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ENGINEERING STUDIES OF COFFEE MILL WASTES IN EL SALVADOR, C. A., OCTOBER 18-NOVEMBER 9, 1960

Hayse H. Black

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

April 1961

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Report to
International Cooperation Administration
United States of America Operations Mission to El Salvador

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By
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Sanitary Engineer Director
Industrial Wastes Consultant

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
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Details of illustrations in this document may be better studied on microfiche.

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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INTRODUCTION

This report pertains to control and treatment of both solid and liquid wastes from processing coffee in El Salvador. It is divided into three parts, namely:

1. Notes on conferences and observations pertaining to wastes from processing coffee in El Salvador during the period October 18 to November 9, 1960

2. Review of technical literature dealing with control and treatment of liquid wastes resulting from the processing of coffee

3. Future research on coffee wastes

NOTES ON CONFERENCES AND OBSERVATIONS PERTAINING
TO WASTES FROM PROCESSING COFFEE IN EL SALVADOR
DURING THE PERIOD OCTOBER 18 TO NOVEMBER 9, 1960

Short term consultation on Industrial Wastes was requested by the U.S. Operations Mission to El Salvador in an airgram dated August 26, 1960 to ICA/Washington. This airgram is included as Appendix A in the report. The writer arrived in San Salvador at 2:25 P.M., October 18, and departed for the United States at 3:00 P.M., November 9, 1960. The following notes appear in chronological order and the memoranda prepared in San Salvador have been reproduced as a matter of record.

Wednesday, October 19, 1960

Mr. Robert Brewer, Sanitary Engineer Advisor, USOM/American Embassy, San Salvador, El Salvador, briefed the writer on the U. S. Operations Mission to El Salvador, with particular reference to his work. The following people were contacted on this date:

Col. Harry W. Miller, Director
United States Operations Mission to El Salvador

Mr. Clinton Smith, Executive Officer
(Deputy to Col. Miller)

Dr. Lamar A. Byers, M.D., Chief,
Health and Sanitation Division and Director
Cooperative Health Service, U.S.O.M.

Mr. Asa Walker, Assistant Executive Officer,
U.S.O.M.

Engineer J. Alfonso Valdivieso,
Direccion General de Sanidad, Division of Engineering,
El Salvador Department of Health

Engineer Alfredo Batlle, Regional Engineer,
Metropolitan District, Sanidad

Dr. Roberto Arevalo, Director,
Division de Laboratorios, Sanidad

Engineer Jorge Alfaro, Sanitary Engineer,
Central Office, Sanidad

Mr. Shelby Cain, Acting Chief, Agricultural Division,
USOM, Santa Tecla

Mr. Valdivieso described the streams in El Salvador as being relatively short, with discharge varying with rainfall. In fact, many of the streams

have no discharge during the dry season. Rio Lempa has the largest drainage basin and the flow in this stream varies from a low of 18 cubic meters per second to a high of 14,000 cubic meters per second.

The seaport of Acajutla is rapidly being developed as an industrial center. Shell Oil Company and Esso Standard Oil Company are both building petroleum refineries in the Acajutla area. It was reported that the Shell Refinery was scheduled to go on stream late in 1961.

Sanitation problems and the need for waste treatment were discussed at some length. The area of El Salvador is approximately 13,000 square miles, comparable to the State of Maryland. It is a mountainous country with a succession of ridges and fertile valleys. There are a number of extinct volcanoes and a narrow coastal plain.

El Salvador supports some 2,700,000 people. This gives a density of population of 130 people per square kilometer. San Salvador is the capital and the largest city, with a population in excess of 200,000.

Dr. Arevalo took us through his laboratories and described his work. He has a limited staff and mostly female technicians. On the day of our visit, there were a large number of blood samples to be examined for syphilis. Equipment appeared to be adequate for the analytical work required.

Dr. Arevalo advised that he was not set up to run sanitary analyses on waste samples. His laboratory does run bacteriological analyses on water samples, principally from San Salvador. Dr. Arevalo indicated that water samples received would average ten per day and four days per week. It was reported that 70% of the water supplied San Salvador came from twelve wells, ranging in depth from 70 to 90 meters. The remaining 30% of the water for San Salvador comes from springs.

An attempt was made to confer with officials of the Instituto Salvadoreno de Investigaciones del Cafe at Santa Tecla. This institute is located some eight miles west of the Sanidad office. Employees at the institute work different hours than Sanidad and we arrived just as the office was closing. We talked with Mr. Shelby Cain, but the Coffee Institute is not a part of the USOM.

Thursday, October 20, 1960

Accompanied by Mr. Alfredo Batlle, a reconnaissance survey was made on this date of the Santa Ana area. This included visits at one finca, two beneficios, and the stream that receives untreated wastes from the Santa Ana area.

It is significant that 33% of the coffee produced in El Salvador is grown in the Santa Ana area. Approximately 20% of the coffee grown in El Salvador is processed by nine beneficios located in close proximity to Santa Ana. In the year 1957, 79% of all exports from El Salvador was coffee.

One finca was visited where coffee cherries were being picked. The term "finca" applies to a farm which grows only one crop per year. The finca visited had the coffee trees planted in rows, 8 feet center to center. Larger shade trees are used to protect the coffee trees and to conserve moisture.

Mr. Frank Wager, Administrator of Rio Zarco Beneficio, conducted us on a tour through his plant. He explained the several steps in processing of coffee and indicated their relation to the liquid waste problem. Except during the peak of the season, this beneficio has an abundance of ground water for process. Mr. Wager is a strong advocate of fresh water use, believing that a superior quality finished coffee results from a minimum reuse of pulp water.

The Rio Zarco Beneficio is one of the largest coffee processing plants in El Salvador. This beneficio can process 13,000 bags (150 pounds each) of coffee cherries in 24 hours. This represents 3900 quintals of finished coffee. The Rio Zarco Beneficio has been processing approximately 120,000 quintals finished coffee per season (Quintal equals 100 pounds).

Mr. Alfonso Alvarez, owner of the El Molino Beneficio, conducted a quick tour of this plant. Dry coffee is transported through this beneficio by a pneumatic system. This system significantly reduces manual labor, but it is said to be costly. The pneumatic system was installed several years ago and its continued use has been possible by the advance in coffee price. There is some question as to the economic feasibility of the El Molino system. The Alvarez family is one of the leading coffee growers in El Salvador.

Mr. Ricardo Perez, President, Fertilizantes Salvadorenos, S.A., invited us to inspect his pilot plant for anaerobic digestion of coffee pulp. We were accompanied by Mr. Alfonso Alvarez and Dr. Victor Ortiz. Dr. Ortiz, former Dean, Department of Chemistry, University of El Salvador, is serving as a consultant to Mr. Perez in the operation of this pilot plant.

The pilot plant consists of two closed metal tanks each two meters in diameter. The digesters were reported to have a capacity of seven cubic meters each, but they were operated at a level of six cubic meters. The digesters have been operated at both 35° Centigrade and 55° Centigrade. Gas production is metered.

This pilot plant had been in operation for some four months. Initially, one digester was operated on 1959 coffee pulp and the other digester was operated on garbage. The digesters were placed in operation by filling two-thirds full with raw sewage, which was held for five days. At the end of this period, coffee pulp was added to the one digester at the following rates:

First day	50 pounds pulp
Second day	100 pounds pulp
Third day	150 pounds pulp
Fourth day	200 pounds pulp
After 14 days	600 pounds pulp per day

At the time of our inspection, both digesters were operating in parallel on 1959 coffee pulp. Contents of each digester is mixed thoroughly three times daily by pumping for 15 minute periods. This agitation breaks up the scum and was believed to provide adequate mixing. Some sludge was being withdrawn every ten days.

It was reported that 100 pounds of coffee pulp produced twenty pounds of inoffensive digested sludge. The pH of the digester contents averages about 7.2. Considering coffee pulp of 20% dry solids, the gas produced amounted to 4.5 cubic meters per 100 pounds of pulp. A good quality gas was being produced. During the first 36 days of pilot plant operation, CO_2 averaged 35% in 24 gas samples. Estimating other constituents in the gas by difference, Dr. Ortiz suggested a digester gas containing the following:

CO_2	35%
CH_4	63%
N	1%
H	1%
H_2S	0.1%

A small gas stove had been installed to demonstrate the use of the gas. Considerable enthusiasm was expressed about the potentialities of pulp fermentation to produce gas which could be used to drive gas engines which in turn would drive generators.

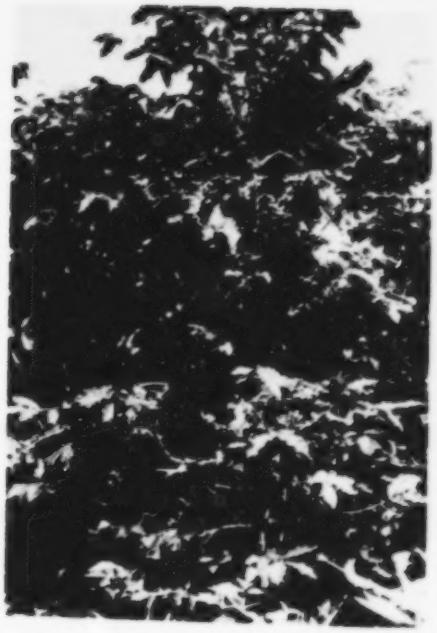
The stream that drains the Santa Ana area was inspected at various points for some ten miles below the city. Ebullition of gas was observed in a small reservoir behind a power dam. This condition, occurring at the beginning of the coffee processing season, indicates the pollutional effect of raw sewage discharged from the city of Santa Ana. See Figures 1-6, inclusive.

Friday, October 21, 1960

Conferred with Dr. Byers and Mr. Brewer to brief them on observations and inspections made in the Santa Ana area on the preceding day. Emphasis was placed on the pilot plant for anaerobic digestion of coffee pulp. It was decided that a conference should be arranged for Monday, October 24, with Ricardo Perez in Santa Ana. It was further decided that Messrs. Brewer, Batlle and Black would go to Santa Ana for this meeting.

Conforming with the suggestion of Dr. Victor Ortiz, we conferred with him at his laboratory office in San Salvador. Messrs. Brewer, Batlle and the writer participated in this conference. Dr. Ortiz wished to inform us of the research he had been conducting on coffee pulp.

Dr. Ortiz advised that he started working on methods for handling coffee pulp in December 1959. Consideration was given to the use of sodium arsenite to control flies that feed on coffee pulp, but this compound was considered to be too hazardous. This is consistent with action taken in certain areas of the United States, where sodium arsenite has been outlawed as a weedicide.



Coffee tree on Finca near Lago de Coatepeque, Santa Ana

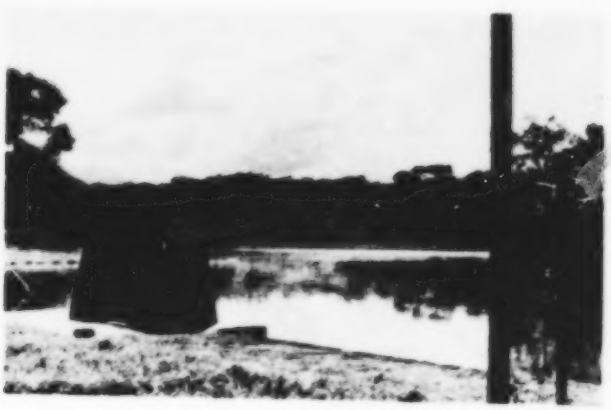
Figure 1

La Laguna Beneficio located at the west edge of San Salvador in the crater of an extinct volcano

Figure 2

Rio Shutiat serves as a source of some process water and occasionally receives some process wastes. **Ateos Beneficio**

Figure 3



Reservoir formed by power dam in stream which drains Santa Ana and environs. There was ebullition of gas in this reservoir when inspected the afternoon of October 20, 1960.

Figure 4

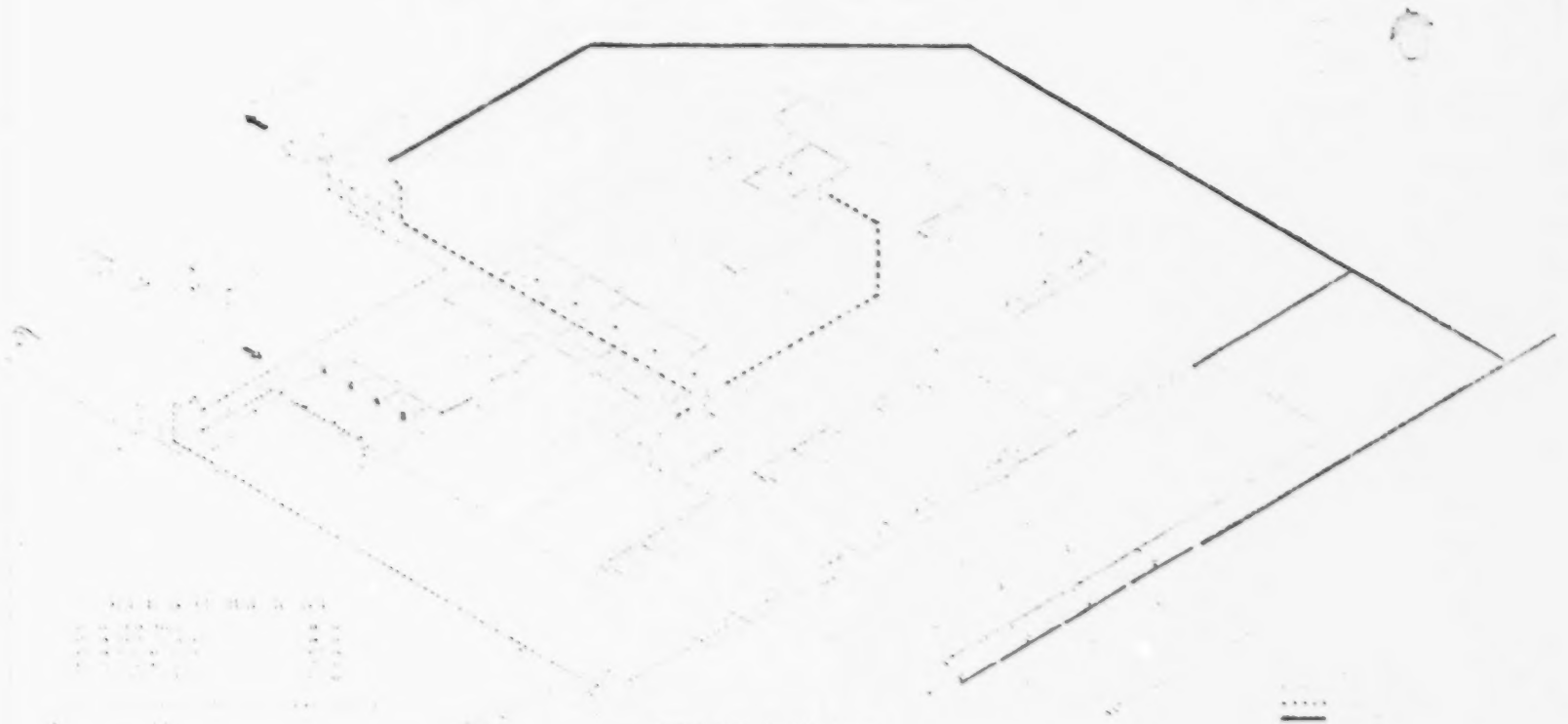


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Figure 5

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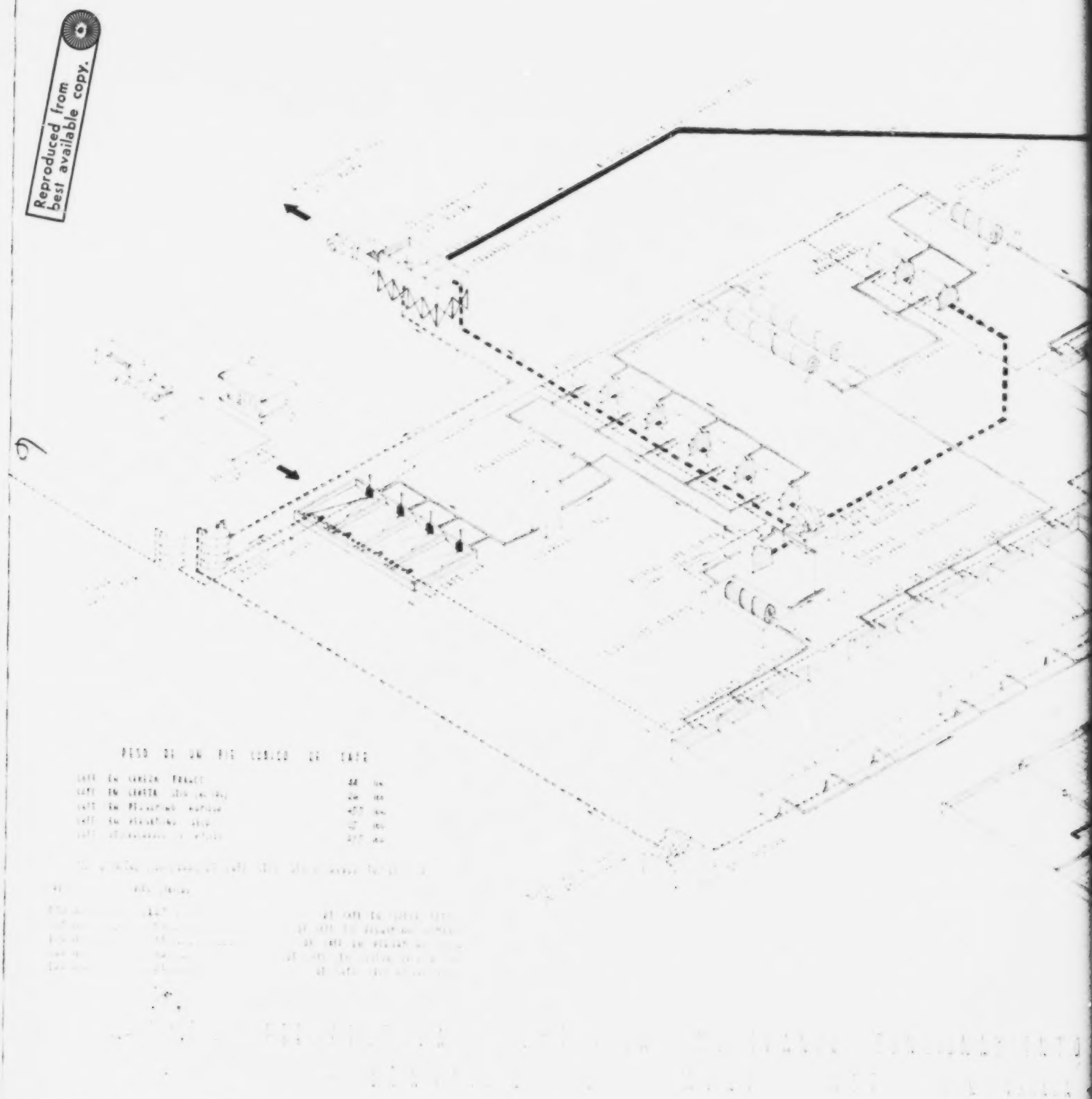

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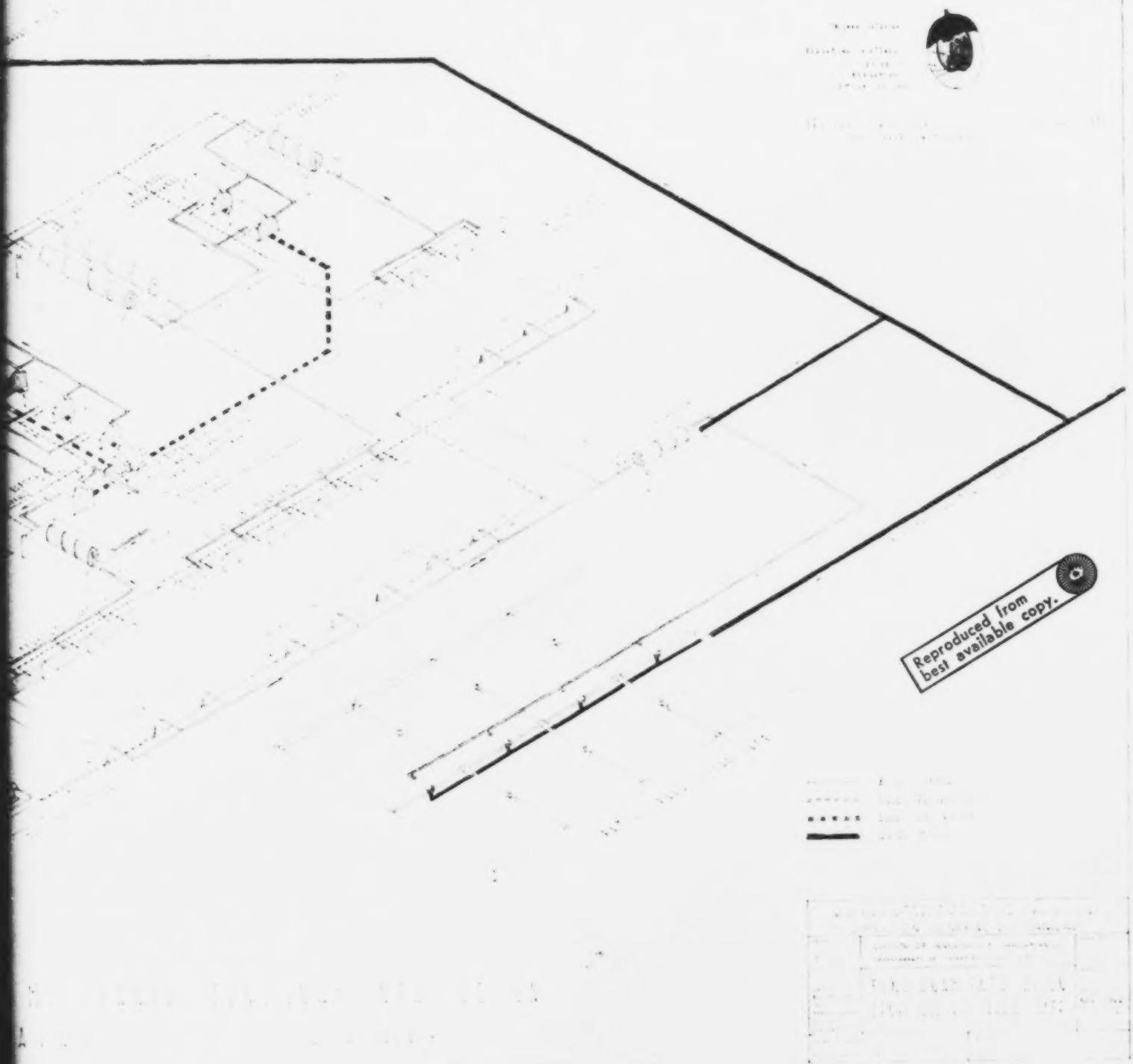

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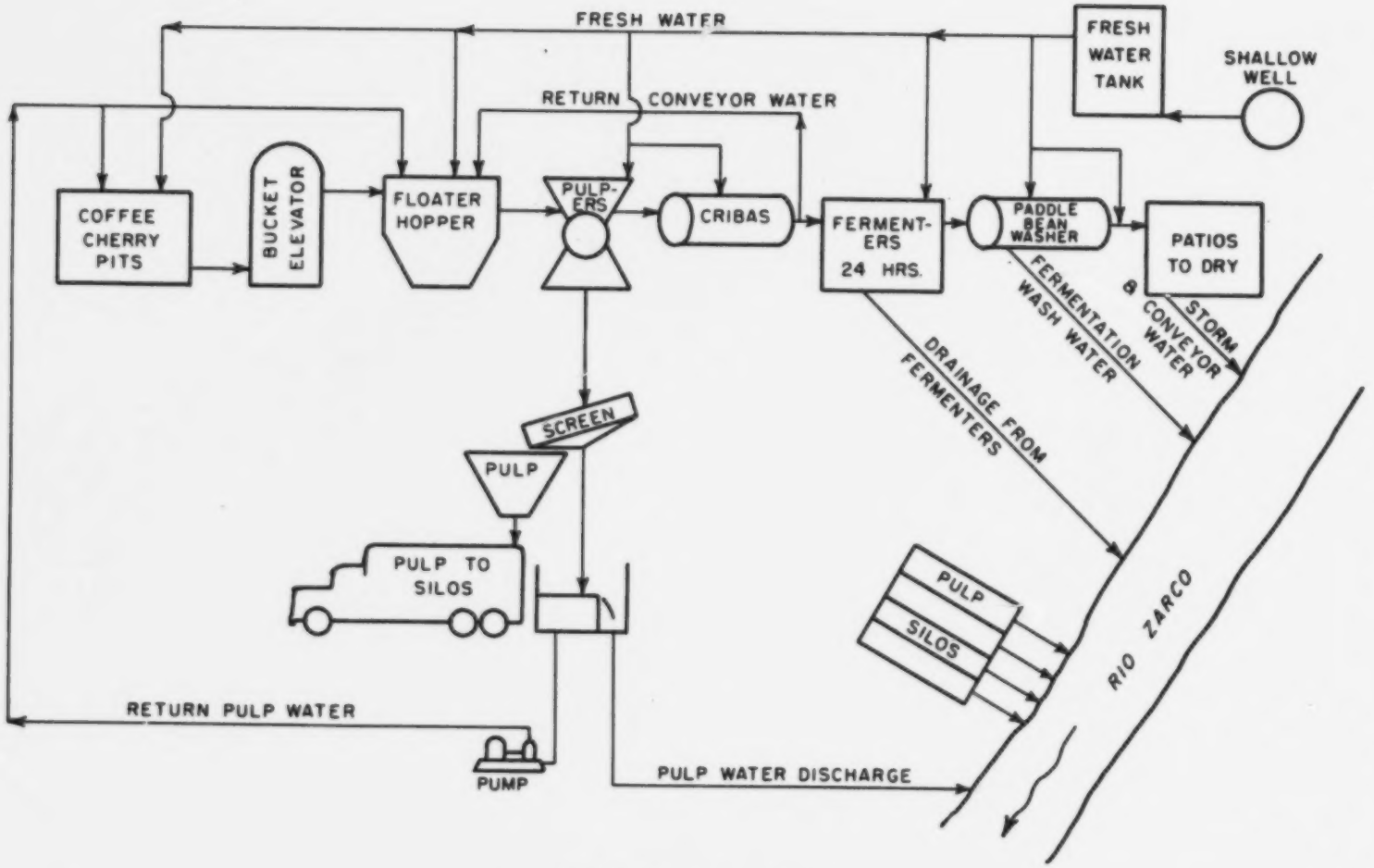
Figure 5



RIO ZARCO BENEFICIO
SANTA ANA, EL SALVADOR

(H.H.B.-NOVEMBER 3, 1960)

Figure 6

Composting was said to hold considerable promise. Laboratory scale composting of coffee pulp resulted in the increase of nitrogen from 1.7% to 3.0% N. The recommended depth for the compost was 1.5 meters (4.92 ft.) Flies are allowed access to the pulp beneath a plastic blanket. Fly eggs hatch and larvae penetrate to within 1 ft. of the ground. Air is blown intermittently into the compost and provision is made to sprinkle water on it if it heats up.

Studies have been made with coffee pulp as a material from which to make wallboard. Pulp for this purpose must contain 10% to 15% moisture. The cost of the binding agent for coffee pulp wallboard is 1 colon per square meter.

It was stated that molasses could be mixed with dry coffee pulp to produce a satisfactory cattle feed. It is understood that cattle feeding experiments have been conducted by several beneficio operators over a period of years. The demand for coffee pulp treated with molasses is lacking in El Salvador.

Dr. Ortiz advised that he had reported to coffee beneficio operators April 21, 1960 on the results of various coffee pulp research projects. This report included digestion to produce methane. Referring to the Santa Ana pilot plant for digestion of coffee pulp, Dr. Ortiz indicated that it would be operated for at least one more month under his direction.

Monday, October 24, 1960

It has been estimated that the nine beneficios located in the Santa Ana area will produce 750,000 quintals of wet pulp in one season. This estimate is based on 200 pounds of wet pulp for each 500 pounds of coffee cherries processed. This available pulp has attracted attention as a by-product which could be processed in a central plant. Concentrated liquid wastes from these nine beneficios could likewise be collected and treated in one central plant.

The potential economic value of the coffee pulp from this concentration of beneficios in Santa Ana has been recognized. We were advised that a corporation had been formed to explore the feasibility of anaerobic digestion of the pulp to produce methane. The methane would be used in gas engines, which in turn would drive generators, and it was expected that a long term contract could be negotiated for sale of the electricity to the public utilities. Mr. Ricardo Perez is President of the sponsoring corporation known as Fertilizantes Salvadorenos, S.A.

Mr. Ricardo Perez and Mr. Alfonso Alvarez visited Germany in August 1960 for the purpose of inspecting digestion systems producing methane gas. Three plants in Germany were investigated. It was reported that each of these plants was being operated on waste agricultural products. The largest German plant received cow manure from a hospital dairy having about 100 dairy animals.

Two German authorities on digestion of agricultural wastes were consulted

by Messrs. Perez and Alvarez. One of these Germans was Ferdinand Schmidt, whose address was given as Deutsche Futterkonservierungsgesellschaft, Verden (Aller), Germany. The other German was Dr. Ing. W. Eggersgluss. We were advised that Mr. Schmidt and Dr. Eggersgluss might come to Santa Ana later during this coffee processing season to supervise pilot plant studies on coffee pulp wastes.

We were advised that the pilot plant operating on silo coffee pulp from the 1959 season had produced quantities of gas ranging from 3.9 to 5 cubic meters for each 100 pounds of pulp. This represents 7.5 to 9.6 cubic feet of gas for each pound of organic material.

Mr. Ferdinand Schmidt prepared a report on the Bihugas Project for "El Molino" (Santa Ana) based on information and coffee pulp samples furnished by Fertilizantes Salvadorenos, S.A. The following basic data were used in the German computations:

1. Fresh pulp 16.8% dry solids, of which 90% is organic. Organic content equals 15.12% based on weight of wet pulp.
   0.70% total N in fresh substance.

2. Pulp from silo. 20.43% dry solids, of which 90% is organic. Organic content equals 18.35% based on weight of silo pulp.
   0.70% total N in fresh substance.

3. Pergamino (parchment), 90.82% dry solids, of which 91% is organic. Organic content equals 82.5% based on weight of parchment.
   0.40% total N in fresh substance.

Computations in the German report were based on an annual production of 32,660 tons of fresh pulp, which represents 90.7 tons pulp per day. Parchment was estimated at 650 tons per year or 1.8 tons per day. Fermentor design was based on pulp data in the following tabulation which appears in the German report:

	Total Quantity	Organic Substance	Dry Substance
Pulpa	90.7t	13,680 kg.	15,230 kg.
Pergamino	1.8t	1,480 kg.	1.630 kg.
Total Filling	92.5t	15,160 kg.	16,860 kg.

The German report considered twelve days retention in the digester and 50% decomposition of the organic matter. Consequently, from a daily charge of 15,160 kilograms of organic substance, we would have 7,580 kilograms transformed into bihugas. This means a daily gas production of 6,820 cubic meters. This represents 7.2 cubic feet of gas per pound of organic matter, which is

slightly less than the minimum production reported from the Santa Ana pilot plant operation.

Mr. Perez made available one copy of Ferdinand Schmidt's report on the Santa Ana proposal, prepared in English, for our review. Comments on this review are given in the notes for October 25.

Tuesday, October 25, 1960

A conference was held at 9:00 AM with Dr. Byers and Mr. Brewer for the purpose of discussing the proposed Santa Ana anaerobic fermentation plant. Following this conference, a memorandum was prepared, subject "Comments on Bihugas for El Molino". A copy of this memorandum appears in this report as Appendix B. Digestion of coffee pulp was further discussed in a conference at 3:00 PM in Santa Ana with the following participating: Ricardo Perez, Eduardo Alvarez, Adolfo McEntee, Robert Brewer, and Hayse H. Black. Mr. Eduardo Alvarez and Adolfo McEntee are Directors in the corporation Fertilizantes Salvadorenos, S.A.

The fermentor design allowed one cubic meter useful volume for each 4.5 kilograms of organic substance. Accordingly, the daily charge of 15,160 kilograms of organic substance calls for useful fermentor capacity of 3,370 cubic meters. Allowing necessary freeboard, total capacity of the fermentors was computed as 4,330 cubic meters. Based on useful capacity, this represents a fermentor loading of 0.28 pound per cubic foot.

Eight digesters were proposed, each with a total capacity of 550 cubic meters. Dimensions of these tanks were given as 8 meters in diameter and 11 meters high. These digesters were interconnected to permit circulation with two independently working pump aggregates.

The German report proposes storage of 21,800 tons of pulp at the central plant after removal of water by centrifuging. This pulp will be stored in 4 pit silos each 10 meters wide, 7 meters deep, and 70 meters long. The estimated cost of these pulp silos was 450,000 D.M.

It was suggested that the fermentors be operated at a temperature of 55° C. (131° F.). This will require the use of some gas to heat the digesters. Thermophilic digestion can frequently be justified by increase in gas production and at a higher rate.

Total cost of this anaerobic digestion plant for coffee pulp at Santa Ana was estimated at 2,500,000 colons. The economic study showed the investment to be amortized in five years and nine months, after which interest on the invested capital would be 21.8%. This favorable return on the investment is not approached by similar digestion plants in the United States.

A. G. Ferrostaal Company, Essen, Germany, was recommended as the contractor for this Santa Ana project. It was proposed to fabricate most of this plant in Germany and to ship the prefab units to Santa Ana for assembly.

Engineering drawings and specifications for this plant had not yet been prepared.

Our attention was directed to a report prepared by Ferdinand Schmidt entitled "Development of the Bihugas Plant Allerhop - Its Capacity and Economical Efficiency" (January 9, 1951). This German bihugas plant is located on the experimental farm Heidehof Allerhop. It has a capacity to handle up to 138 cubic meters feed per day. The CO_2 content of the gas was reported to range between 35% and 40%. The calorific value of the gas varies between 5700 and 6000 Kg-Cal. This bihugas has a higher heat value than normal town gas. It will be noted that the heating value is reported as Kg-Cal. per standard cubic meter.

No water is added to the Allerhop bihugas plant. Some sludge is withdrawn every two to three weeks. There is no loss of nitrogen. The nitrogen being nonvolatile is concentrated in the sludge.

The estimated production of 6820 cubic meters of bihugas daily at the proposed Santa Ana plant amounts to 2,450,000 cubic meters annually. Transformed to electric current, this represents 4,050,000 KWH. Considering a value of two cents per KWH, the gas which could be produced from the coffee pulp in the Santa Ana area should return $81,000.00 per year in U.S. currency.

The German reports indicate that bihugas normally contains 62% methane and 38% CO_2, with traces of nitrogen, oxygen, hydrogen, and hydrogen sulfide. The gross heating value of this gas is 5900 K-Cals. per cubic meter (660 BTU/cu.ft.) Compared with other sources of energy, one cubic meter of bihugas is equivalent to 1.5 KWH electrical energy or 0.45 Kg. of Diesel oil. One kilogram of propane is equivalent to 2.45 cubic meters of bihugas, considering a heating value of 11,000 Kg.-Cal. per Kg. propane.

Mr. Perez expects to use 500 GPM of the concentrated wastes to pump the coffee pulp to the central plant. This gives a liquid volume of 720,000 GPD. Considering a 120 day season, this gives a total volume of liquid wastes of 86,400,000 gallons or 265 acre feet.

Attempt was made to estimate the maximum population equivalent of liquid wastes from processing coffee in El Salvador. Currently, annual production of coffee amounts to approximately 180,000,000 pounds of finished coffee annually. Considering a season of 120 days, this means a daily average of 1,500,000 pounds of finished coffee. It was stated that the maximum production at the Rio Zarco Beneficio was four times the average. The report published by Capt. Paul C. Ward indicates an average of 0.64 pounds of 5-day BOD (20° C) for each 100 pounds of coffee cherries milled. This means 3.2 pounds BOD for each 100 pounds of finished coffee. Based on this BOD value, 15,000 quintals of finished coffee per day would give a population equivalent of 1,152,000 for the coffee industry in El Salvador.

Wednesday, October 26, 1960

We learned of the change in Government when we arrived at the office. President Lemus was replaced by a Board of Governors composed of three army officers and three civilians. Most Government offices were closed to permit Government workers to participate in the celebration. SCISP closed at 12:00 noon.

Time was devoted to review of Sanidad reports pertaining to the handling of coffee wastes. In addition, English publications on the treatment of wastes from processing coffee were re-examined.

There are three organizations in El Salvador that devote full time to the interests of the coffee industry. The main office of each of these companies is located in San Salvador. The names of these companies, their address, and their respective managers are listed below:

1. Compania Salvadorena de Cafe
   11th Calle Oriente #801
   Manager - Dr. Adalberto Belanos

2. Asociacion Cafetalera de El Salvador
   6th Avenida Sur #133
   Manager - Sr. Carlos Cordero d'Aubuisson

3. FEDECAMA - Federacion Cafetalera de America
   6th Calle Oriente #223
   Manager - Sr. Baltazar Ferreiro

Thursday, October 27, 1960

Two memoranda were prepared on this date. One is designated "Treatment of Coffee Wastes" and this is included as Appendix C. The subject of the second memorandum was "Coffee Process Wastes Investigation, 1960-1961 Season" which has been reproduced as Appendix D. For coffee pulp see Appendix E.

We conferred at 2:00 PM with Col. Miller and Dr. Byers at the Point IV Office. The principal subject for discussion was the proposed project at Santa Ana for fermentation of coffee pulp. The program for the remainder of my assignment in El Salvador was outlined.

Friday, October 28, 1960

Engineer J. Alfonso Valdivieso and the writer visited the Institute Salvadoreno de Investigaciones del Cafe at Santa Tecla. We conferred with the following people: Tomas Vilanova, Director of the Institute; Fernando Suarez de Castro, Technical Director of the Institute; Miss Flora Espinoza, Chief Chemist at the Institute; Juan Balette, Agriculture Cooperative Service (USOM).

Mr. Vilanova referred to an experimental plant for processing coffee that allegedly used a minimum of water. This plant processed 300 quintals finished coffee per day. This experimental plant dates back to 1939 and it is no longer operating. Mr. Vilanova indicated that this was a good example of minimum water use and he was under the impression that the operation of this plant was described in the technical literature.

Mr. Roberto Pacas Talleres Unidos, Santa Ana, El Salvador, was mentioned as a Mechanical Engineer interested in designing and building new beneficios. It was stated that Mr. Pacas should have good data on water use. In addition to the new beneficios which he is constructing, he also serves as Consultant to existing beneficio operators.

Several years ago Mr. Vilanova developed a caustic treatment for removal of mucilage from the parchment. Elimination of fermentation speeds up the coffee processing. It was stated that caustic treatment required closer control than fermentation and if the parchment is broken, the caustic causes discoloration of the bean. The bean turns black, thereby reducing its quality. This caustic treatment process is described in a publication entitled "Beneficiado rapido y eficiente del Cafe mediante el uso de Soda Caustica" by Roberto J. Carbonell and Tomas Vilanova. The above publication is Technical Bulletin No.13 published in November 1952 by Ministerio de Agricultura y Ganaderia Centro Nacional de Agronomia Santa Tecla, El Salvador, C.A.

Mr. Fernando Castro has been at the Santa Tecla Institute for some two years. He formerly worked on coffee waste problems in Columbia, South America. The Columbia experiments with coffee pulp included:

1. Fermentation
2. Fertilizer
3. Cattle feeding
4. Torula yeast

Mr. Castro is a strong advocate of the use of coffee pulp as a fertilizer. He is satisfied that this is the only economical use. Theoretically, all the pulp produced in El Salvador in one season could be applied to one-fifth of the coffee trees at a rate of 25 pounds per year. Accordingly, coffee trees in El Salvador could be fertilized with pulp once every five years.

Fertilizer studies made by Mr. Castro have included observations of fly larvae. He reported more than 1,000 fly larvae found in ten cubic centimeters of fresh coffee pulp. When pulp is applied to a coffee tree at the rate of 25 pounds per tree, the fly larvae count in ten cubic centimeters was reduced to ten to fifteen. If fresh pulp is worked into the soil around the coffee tree, only one or two fly larvae may be expected in a ten cubic centimeter sample. Mr. Castro recommends application of the coffee pulp as fertilizer at the beginning of the wet season. We were shown a number of photographs illustrating the growth of plants fertilized with coffee pulp. These were impressive.

Mr. Castro has published his observations on the value of pulp as a fert-

ilizer in a recent article entitled "Valor de la Pulpa de Cafe como Abono". This article appears in Mayo-Junio 1960 issue of the magazine El Cafe de El Salvador published by Asociacion Cafetalera de El Salvador.

Miss Espinoza conducted a tour of the Institute Chemical Laboratory. This laboratory is equipped to run most chemical analyses pertaining to coffee. This laboratory is only about two years old. It is well planned and well equipped. It was noted that provision had been made to run twelve Kjeldahl nitrogens simultaneously.

Dr. Ortiz had arranged for the Institute Chemical Laboratory to run certain analyses on coffee pulp and supernatant liquor from the digester. Samples included dry coffee pulp, two samples of digested pulp, and three samples of digester supernatant liquor. Analytical determinations on these coffee waste samples included: nitrogen, potassium, phosphorus, and solids, both total and volatile. Mr. Castro expressed interest in running analyses on coffee wastes.

Mr. Valdivieso expressed the opinion that it would be very difficult to use coffee pulp as fertilizer and control flies. He stated that he had seen layers of coffee pulp twenty centimeters thick on coffee ground at the fincas.

Mr. Balette conducted a tour of the USOM Laboratories, which are adjacent to the Institute at Santa Tecla. This is an agriculture cooperative service on a fifty-fifty basis. In other words, cost of these investigations are borne equally by USOM and the Government of El Salvador. We observed some interesting collections of insects. This research covers virtually every phase of agriculture in El Salvador, with the exception of the coffee industry.

In the late afternoon, the writer accompanied Alfredo Batlle and Guillermo Arbizu on an inspection of the sewage treatment works serving a housing development at the University of El Salvador. Mr. Arbizu is Chief of the Inspection Department of Mr. Valdivieso's division. This sewage treatment works is designed to provide complete treatment for 5,000 people, but the contributing population was reported to be only about 3,000 at the present time. Infilco equipment was used for the clarifiers, trickling filter, and the digester. This treatment works was providing satisfactory treatment, as evidenced by a clear effluent. There was no control laboratory at the plant.

Monday, October 31, 1960

Alfredo Batlle, Robert Brewer, and the writer visited the Rio Zarco Beneficio at Santa Ana for the purpose of studying water requirements. We were interested in water reuse as well as available fresh water. Process water is furnished by one well, which is 30 ft. in diameter and 36 ft. deep.

Fresh water pumps consist of two installed directly over the well and five centrifugal pumps located in a building alongside the well. Frank Wager, Administrator of Rio Zarco Beneficio, was of the opinion that existing fresh water pumps could provide 30,000 gallons per hour. These well pumps discharge into a header at the well site and four parallel pipe lines lead from this header to an elevated storage tank.

It was decided to determine the capacity of these well pumps by timing the rise in the storage tank. This storage tank was 21.5 ft. in diameter. This gives a volume of 226 gallons per inch of depth. Four of the centrifugal pumps operating simultaneously pumped six inches of water in the storage tank in one minute and forty seconds, which represents approximately 820 GPM, or 49,200 GPH. The old large pump delivered six inches of water in the storage tank in one minute and fifty seconds, which represents 740 GPM, or 44,400 GPH. It is evident that with the present water level in the well, both of these pumping systems are capable of delivering approximately 50% more water than was estimated.

Pulp water is reused at only two places at Rio Zarco, namely

1. Cherry receiving pits
2. Floater hopper, from which cherries are distributed to the pulpers

It should be pointed out that fresh water is also supplied to both the receiving pits and to the floater hopper. Maximum reuse of pulp water occurs as the supply of fresh water diminishes. It was reported that the water level in the well dropped significantly during the peak of the coffee processing season. See Figures 6-13, inclusive.

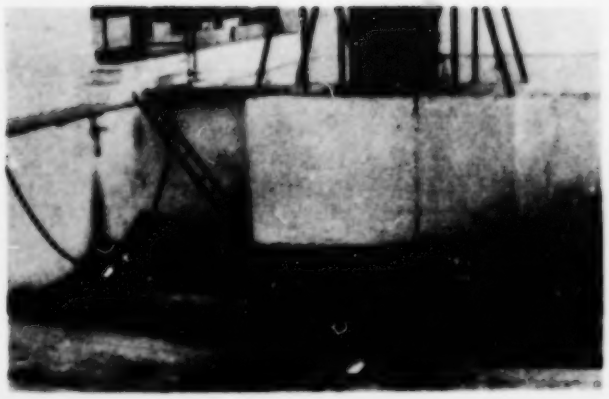
Tuesday, November 1, 1960

We conferred for a short time with Messrs. Valdivieso and Alfaro. There was some discussion of analyses that could be made at the Santa Tecla Institute on fermentation wastes from the Santa Ana Pilot Plant. It was thought that Sanidad might ask the Institute to run the following analyses on fermentor wastes: Nitrogen, potassium, phosphorus, solids, pH, alkalinity, oxygen consumed, BOD, volatile acids, and gas analysis.

Mr. Valdivieso advised that representatives of the coffee industry might buy an incubator for use by Sanidad for waste studies. He also indicated that Dr. Ortiz had invited us to meet with him in Santa Ana Thursday afternoon, November 3. Dr. Ortiz desired to acquaint us with the work he had been doing for the coffee industry. This included both fermentation and composting; the latter work made use of flies to increase the nitrogen content of the pulp compost.

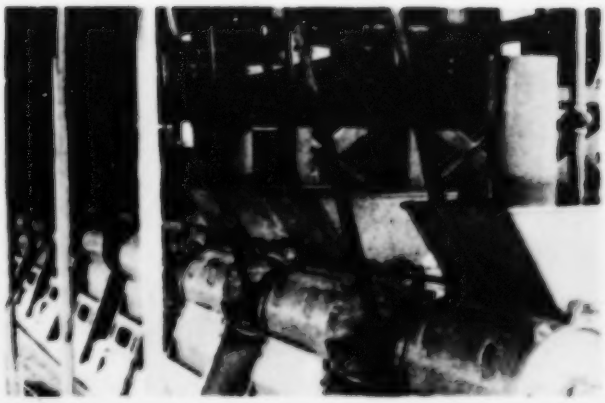
Messrs. Batlle, Alfaro, Brewer, and the writer visited the Ateos Beneficio for the purpose of inspecting the lagoon disposal system. This beneficio is located 30 kilometers (18 miles) west of San Salvador. The Ateos Beneficio was reported to have a capacity to process 36,000 quintals of coffee cherries per day or 7200 quintals finished coffee. Some of this coffee may be processed at other beneficios.

The Ateos Beneficio has provided some twenty lagoons for storage of pulp water and fermentation water. These lagoons have been constructed in an area between the beneficio and Rio Shutiat. Most of these lagoons were dry, even



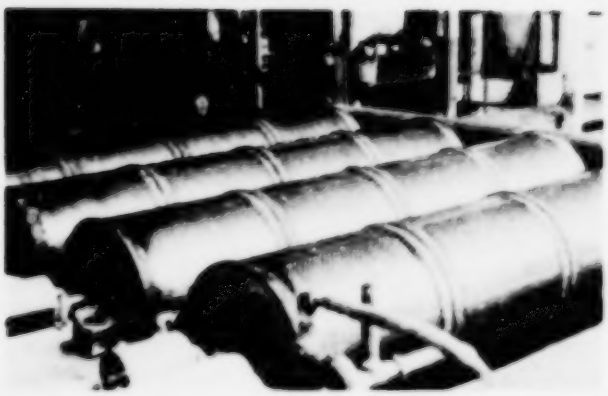
Coffee cherry receiving pits and bucket elevator which conveys cherries to floater hopper ahead of pulpers, Rio Zarco Beneficio, Santa Ana

Figure 7



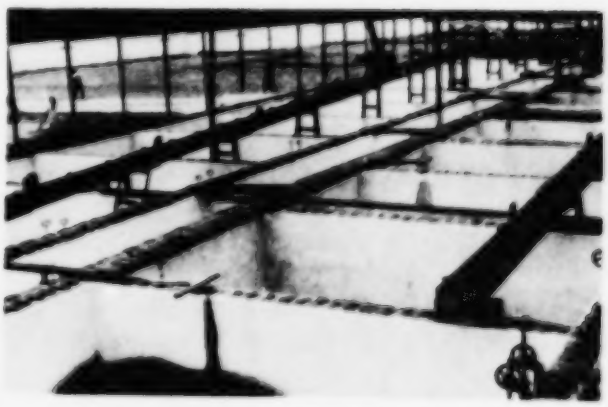
Coffee pulpers, Rio Zarco Beneficio

Figure 8



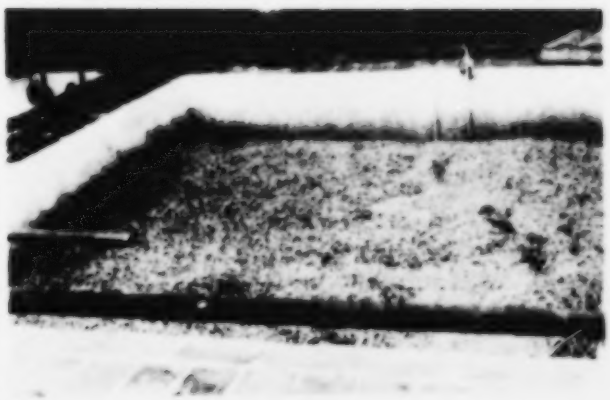
Cribas used to separate coffee beans from unpulped cherries which are returned to repulpers, Rio Zarco Beneficio

Figure 9



Fermenter vats with coffee drying patios in the background, Rio Zarco Beneficio

Figure 10



The process of fermenting the protopectine so that it can be washed from the parchment, Rio Zarco Beneficio

Figure 11

Elevated screen, and hopper for dewatered pulp on left, with horizontal paddle type washer, right center, used to remove fermentation products from parchment, Rio Zarco Beneficio

Figure 12

Fermentation products are frequently washed from the coffee bean by passing through two centrifugal pumps in series as observed at Oromontique Beneficio, Santiago de Maria

Figure 13

though heavy rains preceded our inspection. It would appear that water drains freely from these beds. See Figures 14-22, inclusive.

Pulp was being dewatered by means of expellers. The dewatered pulp was being trucked to pit silos a short distance east of the beneficio. A considerable amount of pulp water was returned from the screens for reuse in process. Expeller liquor flowed to a sump beneath the dewatering system.

Some pulp water was being disposed of in a lagoon adjacent to Rio Shutiat and some was being bypassed directly to the river. Because of recent rains, there was considerable discharge in Rio Shutiat. The amount of pulp water entering the stream was not known, but apparently dilution was adequate.

Wednesday, November 2, 1960

This date in El Salvador corresponds to Decoration Day (May 30) in the United States. It was a national holiday.

Thursday, November 3, 1960

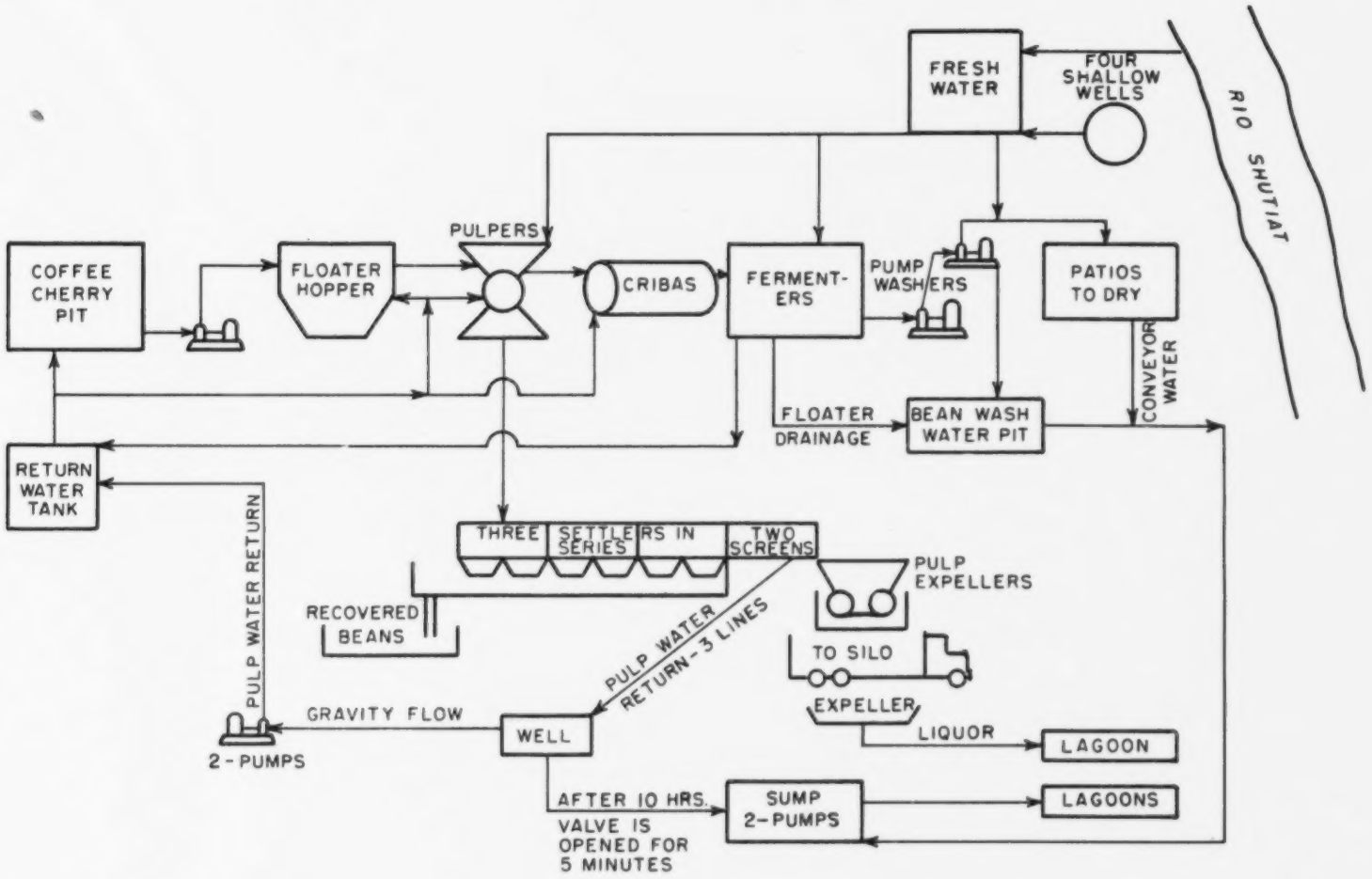
A number of pictures were taken in the forenoon at Rio Zarco Beneficio, Santa Ana. The objective was to photograph equipment and facilities employed in processing coffee in a modern beneficio. Several of these pictures are included in this report. This work was interrupted by a rainstorm.

Conforming with an invitation from Dr. Victor Ortiz, the writer met him and Messrs. Valdivieso and Alfaro at Coscafe Beneficio, Santa Ana, at 3:00 PM. Dr. Ortiz was interested in giving us a complete picture of the research in which he was engaged for the coffee industry. He particularly wanted us to see the coffee pulp fermentation pilot plant and to inspect some of the equipment he expected to use later in the season for composting studies.

We were first shown a sample of finished fertilizer prepared by composting and the use of flies to increase fertilizer value. We were told that this particular sample contained approximately 4% each of nitrogen, potassium, and phosphorus. The system of composting recommended by Dr. Ortiz would include the following:

1. Fresh coffee pulp is piled on top of the ground to a depth of 1.5 meters.

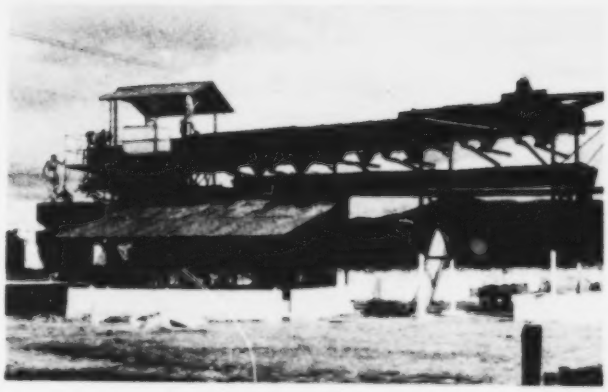
2. Plastic pipes, 4" diameter, and 30' long, are placed on the bottom of the compost pile. Holes 1/4" in diameter are spaced 6" apart longitudinally and 90° apart circumferentially on this pipe. If the temperature in the compost heap goes below 50° Centigrade, air is introduced through this plastic pipe instead of turning the pile. The optimum temperature was reported to range between 50° Centigrade and 70° Centigrade. This proposed compost study contemplated using eleven lengths of this 30' plastic pipe.



ATEOS BENEFICIO
ATEOS, EL SALVADOR

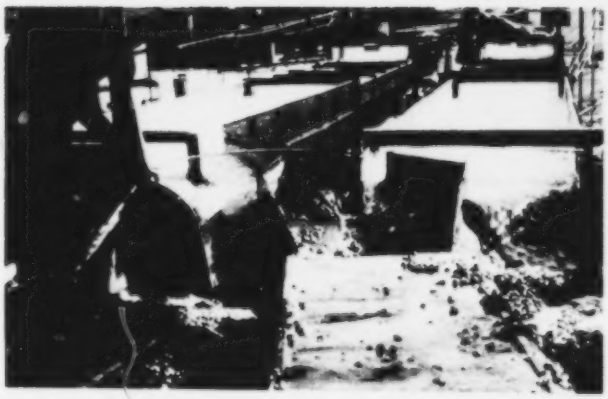
(H.H.B. NOVEMBER 4, 1960)

Figure 14



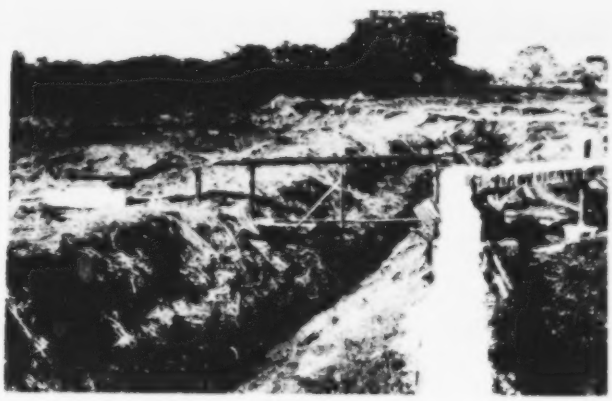
Settlers for recovery of coffee beans from the pulp, flat screens and expellers for dewatering pulp at extreme left, Ateos Beneficio.

Figure 15



Two sets of three settlers each operating in parallel ahead of two flat screens used to recover coffee beans and to dewater pulp, Ateos Beneficio

Figure 16



Foam overflowing waste water flume as shown here provides food for flies. Lagoons for storage of pulping water and fermentation wash water are located on both sides of ditch to left of flume, Ateos Beneficio

Figure 17

Flume carrying waste water and lagoons for storage of liquid wastes from processing coffee, Ateos Beneficio

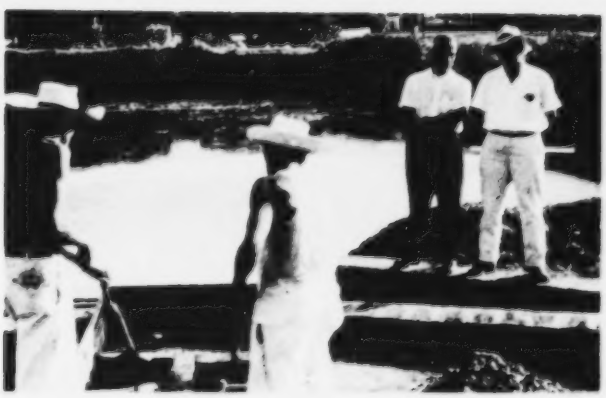
Figure 18

Two Healdsburg expellers, Healdsburg, Calfifornia operating in parallel and dewatering screened pulp, Ateos Beneficio

Figure 19

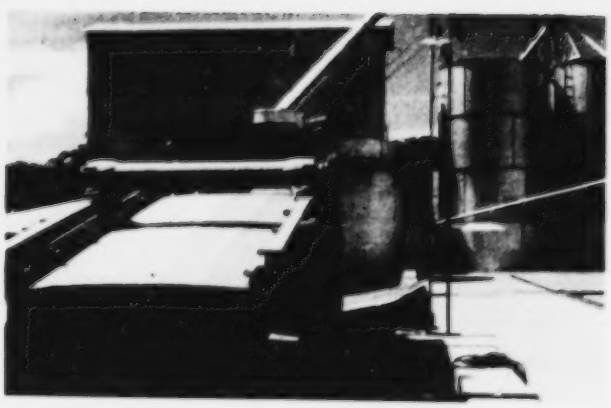
Pit silo for storing coffee pulp, Ateos Beneficio

Figure 20



Manually cleaned flat screen for recovery of coffee beans and pulp as waste flows from flume into one of the lagoons, Ateos Beneficio

Figure 21



Vibrating screen for dewatering pulp, Oromontique Beneficio, Santiago de Maria

Figure 22

3. This equipment included smaller perforated metal pipe to be mounted over the compost heap for a water spray. Water is sprinkled on the compost when necessary to maintain moisture and to control maximum temperature if and when the compost heats up.

4. Fresh coffee pulp contains sugars which attract flies. Accordingly, the compost is first exposed to encourage deposition of fly eggs. After 7 days, and before the fly eggs hatch, the compost is covered by a plastic cloth, entrapping the flies. Plastic cloth to be used for this purpose was in strips 6 yards wide and 50 yards long. Six to eight hours after deposition, fly eggs hatch into larvae (maggots) which grow rapidly and are fully developed in 4 or 5 days. Each larva then becomes a pupa and in another 5 days the adult fly emerges from the pupa. Dr. Ortiz advised that fly treatment of the compost was completed in 30 days.

Following inspection of the equipment to be used on the full scale compost study at the Coscafe Beneficio, we drove to the site of the coffee pulp fermentation pilot plant where we met Ricardo Perez, President, Fertilizantes Salvadorenos S.A. Messrs. Perez and Ortiz reviewed for us the design basis and operation results of the pilot plant. We were advised that expellers would probably be used for dewatering pulp before it is charged to the digesters. The expeller liquor would constitute a concentrated, highly pollutional waste. Mr. Perez stated that digester supernatant and filtrate from dewatered sludge would be hauled to the fincas by the same people who took the sludge for fertilizer.

In response to an inquiry regarding gas analysis, Dr. Ortiz advised that CO_2 was the only determination made. The remainder of the gas was considered combustible. The results of 24 analyses showed a minimum CO_2 of 15% and a maximum CO_2 of 45%. Dr. Ortiz believes that the gas can contain as much as 45% CO_2 and still be acceptable.

Mr. Perez informed us that he had talked with the senior Batlle brothers regarding fermentation of coffee pulp to produce methane and power. He indicated that the Batlle brothers were very much interested in this proposal. Mr. Perez also reported that the Batlle brothers believed that it was possible to reduce water consumption to 50 gallons per quintal of finished coffee. It is significant that the Rio Zarco Beneficio presently uses about 300 gallons of fresh water per quintal of finished coffee.

Opportunity was afforded to discuss the overall coffee waste problem with Mr. Valdivieso on our return trip to San Salvador. Mr. Valdivieso briefly described a new beneficio that he and Mr. Alfaro had inspected in company with Dr. Ortiz earlier in the afternoon en route to Santa Ana. He referred to the Pasatiempo Beneficio which had been designed and constructed by Roberto Pacas. This compact beneficio processes 75 quintals of finished coffee per hour and uses only 40 gallons of fresh water per quintal of finished coffee. The pulpers use 10 gallons of water and the fermented bean washer requires 30

gallons of fresh water per quintal of finished coffee. Mr. Valdivieso expressed the opinion that this new type beneficio indicated a trend in decentralizing beneficios and the processing of coffee.

We discussed the rather extensive lagoon system for handling coffee wastes at Ateos Beneficio. Mr. Valdivieso reported that the Ateos treatment system costs 50 to 60 centavos per quintal of finished coffee. Mr.Valdivieso stated that he would talk with the new Minister of Health, at the first opportunity, regarding complete treatment for both domestic and industrial wastes being produced in the Santa Ana area. Decision in this matter has direct bearing on the proposal to produce methane from coffee pulp by anaerobic fermentation.

Friday, November 4, 1960

Alfredo Batlle and the writer visited the Ateos Beneficio for the purpose of investigating water use and reuse. This is one of the largest beneficios in El Salvador. The survey of beneficios conducted by Sanidad indicated that the Ateos Beneficio processed 171,000 quintals of finished coffee in 1959. This was reported to be all coffee from fincas controlled by Ateos interests. Mr. Alfredo Schonborn is the Administrator of the Ateos Beneficio. Opportunity was afforded to take additional pictures of process equipment.

Process water is normally furnished by four shallow wells. The water level drops in these wells as the season progresses. Provision has been made to supplement these wells by water taken from the Shutiat River.

Coffee pulp is pumped from the pulpers to the dewatering system located adjacent to the lagoon area. The pulp first passes through three settlers in parallel for recovery of coffee beans, thence over flat screens. Screened pulp passes through two Healdsburg expellers operating in parallel for further dewatering. Filtrate passing the screens gravitates to a well from which it is pumped to the return water tank for reuse in the cherry pits, floater hopper, pulpers, and cribas.

The Ateos Beneficio reuses a significant quantity of pulp water and drainage from the fermentors. Bleedoff from this pulp water system occurs at the pulp water well by opening a valve for approximately five minutes after ten hours operation. Additional pulp water is released from the system in the form of fermentor drainage from floater coffee beans. Pulp expeller liquor drains to a lagoon. This arrangement is shown on the Ateos Beneficio Flow Diagram, Figure 2.

Mucilage is washed from the fermented coffee beans by agitation received in two open impeller pumps operating in series. These pumps lift the beans from ground level to overhead hoppers from which the beans are distributed by fresh water to patios. Bean wash water drains to a pit from which it flows to the waste sump where two pumps lift the waste into lagoons. Fresh water used to convey beans to the patios likewise drains to the sump.

It would seem that this water should be returned to the system for reuse.

A flat screen was located at the end of the flume which carried wastes to the lagoons. This was the final effort to recover coffee beans from the waste. These were flat plate screens of the same type that was located ahead of the pulp expellers. Five men were employed at the expeller to squeegee screened pulp from the screen into the hopper feeding the expellers. Another man was kept busy rodding pulp into the expeller. Two men were used to keep the screen clean that was located at the edge of the lagoon.

The principal features of interest at the Ateos Beneficio were:

1. Magnitude of the operation
2. Extensive waste lagoon system
3. Pulp screens and expellers
4. Settlers for recovery of coffee beans
5. Extensive pulp water reuse
6. Open impeller pumps for washing fermented coffee beans

Monday, November 7, 1960

In company with Robert Brewer and Domingo Sossa, Region 3 Engineer, the writer inspected the Pasatiempo Beneficio. Guillermo Montoya was the beneficio owner. Mr. J. Roberto Pacas T., designer of this beneficio, conducted a tour through the plant and described its salient features. Mr. Pacas gave his mailing address as:

Talleres Unidos
Santa Ana, El Salvador

Mr. Pacas' design is an innovation in the processing of coffee. It is characterized by simplicity and compactness. It is designed to process 750 quintals of finished coffee in a ten hour day. A classifier ahead of the pulpers separates the coffee cherries into two sizes. The pulpers operate on ten gallons of fresh water per quintal of finished coffee. Fermented beans are washed in a two stage countercurrent system. Fresh water is used in the second stage and amounts to thirty gallons per quintal of finished coffee. Fresh water requirements of only forty gallons per quintal of finished coffee represents the minimum thus far achieved.

The Pasatiempo Beneficio was constructed in 150 days (June to October). Mr. Pacas constructed two other beneficios of the same type during this period. The other two beneficios differ in that they do not have classifiers for the raw cherries. The Pasatiempo Beneficio was reported to cost 88,000 colons, which included the coffee drying patios. The coffee patio alone costs about 40,000 colons per hectare. In the design of patios, six square meters area are allowed for each one hundred pounds of coffee, considering a ten day drying period.

Mr. Pacas has also designed a portable coffee beneficio which can be operated at the finca. This unit can process fifty quintals of finished coffee per ten hour day. The mobile pulper was reported to require thirty gallons of fresh water to start up and three gallons of fresh water per one hundred pounds of finished coffee. This portable beneficio will accomplish the fermentation step in bags. Water requirements for the bean washer were not recorded. Mr. Pacas plans to prepare a description of these beneficios and an outline of operating procedures for the benefit of operators and others who may be interested.

Pictures were taken of the Pasatiempo Beneficio designed by Mr. Pacas. These reveal interesting structural features and a layout which reduces the number of pumps to a minimum. This open construction reduces first cost but corrosion will undoubtedly be more of a problem than it is in the conventional enclosed beneficio. See Figures 23-29, inclusive.

Liquid wastes from the Pasatiempo Beneficio will be disposed of in shallow wells. These wells were being located on low ground adjacent to the patios. Decentralization of the coffee beneficios and reduced water use promise to alleviate the problem of liquid waste disposal. Reduced capital investment and anticipated low operation costs promise to make the Pacas designs attractive.

In the afternoon, Robert Brewer and the writer visited La Laguna Beneficio, which is located at the west edge of San Salvador in an extinct volcano crater. We met Walter T. Deininger, owner of the beneficio, but most of our time was spent with Francisco Altschul, Administrator.

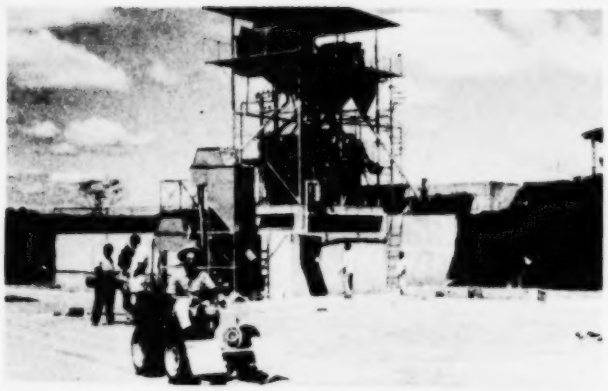
Operators of La Laguna Beneficio have had considerable experience with feeding coffee pulp to cattle. Mr. Altschul advised that 110 pounds of dry coffee pulp were equivalent to 100 pounds of corn. He further indicated that one-third of the shelled corn ration could be replaced with coffee pulp. Mr. Deininger and his associates have demonstrated the feasibility of feeding coffee pulp, but other systems of using this by-product have been investigated.

Mr. Altschul seemed impressed with the Indore Process which was developed some thirty five years ago in India by Sir Albert Howard. The Indore Process is described in the following references:

1. Gotaas, Harold B., "Composting, Sanitary Disposal and Reclamation of Organic Wastes", World Health Organization, Monograph Series No. 31 (1956)

2. Van Vuren, J.P.J., "Soil Fertility and Sewage", Faber and Faber Limited, 24 Russell Square, London (1948)

It was reported that composting, in accordance with the Indore Process, produced excellent humus from coffee pulp in ninety days. The compost consisted of one third coffee pulp and two thirds trampled straw or barnyard



Pasatiempo Beneficio desígned and constructed by Roberto Pacas shown operating the tractor coffee spreader. This beneficio processes 750 quintals of finished coffee per ten hour day and uses forty gallons of fresh water per quintal or 30,000 g.p.d.

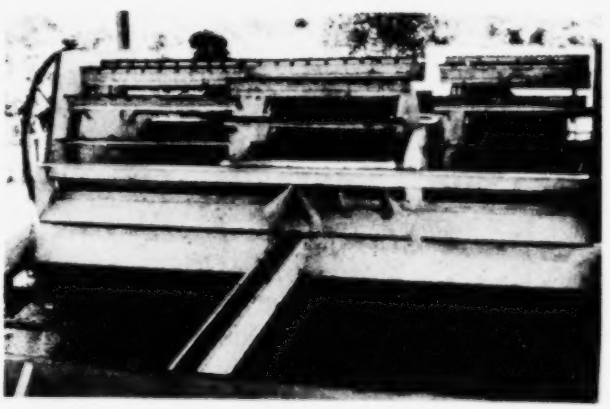
Figure 23

Pasatiempo Beneficio with Izalco in the background Classifiers and cribs on upper level, six pulpers on lower level, two stage counter current bean washer on extreme left. Cost 88,000 colons including coffee drying patios

Figure 24

Coffee cherry classifier ahead of pulpers, Pasatiempo Beneficio

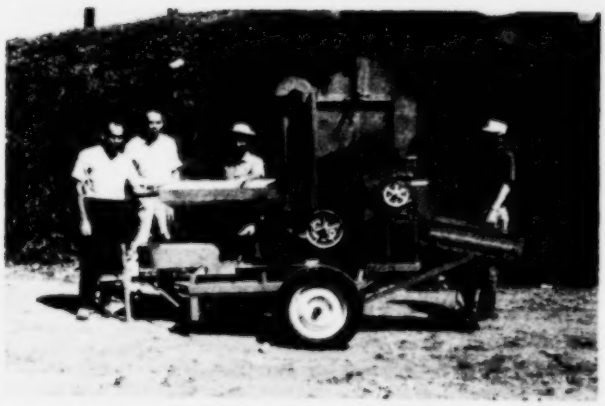
Figure 25



Cribas employing shaker screens, Pasatiempo Beneficio

Figure 26

Three of six pulpers, Pasatiempo Beneficio
Figure 27



Portable coffee beneficio designed by Roberto Pacas. This unit processes 50 quintals finished coffee per ten hour day. Left to right, Robert Brewer, Roberto Pacas, Guillermo (William) Montoya owner of beneficio, Domingo Sossa, Region III Engineer.
Figure 28

Sewage treatment works for housing development, University of El Salvador. Designed for 5000 people with an estimated 3000 presently connected.
Figure 29

manure. The material was turned three times in ninety days.

Silos are used to store coffee pulp when the patios are needed to dry beans. Later in the season, pulp is removed from the silos and dried on available patios. The silos had false bottoms, which allowed juice to drain into the ground.

Referring to process, Mr. Altschul made it quite clear that he was an advocate of using clean water, in order to produce the highest quality coffee. He indicated that some pulp water was reused, but not very much. They ferment coffee beans for a period of twenty to thirty six hours. He stated that ripe coffee cherries had more sugar and fermented more rapidly than green cherries.

This volcano crater, in which La Laguna Beneficio is located, was formerly a lake. Following an earthquake in 1876, this lake disappeared. Process water is obtained from wells located in this lake bed. Beneficio officials are concerned about contamination of this ground water with liquid wastes. Disposal of liquid wastes into wells was discontinued for this reason. Surface land disposal is the only alternative. The practice now is to pump liquid wastes onto nearby land using several plots intermittently. The water percolates into the ground and when the ground surface is dry, it is plowed to maintain porosity.

Mr. Altschul offered to cooperate in any way possible on research directed toward treatment of coffee processing wastes. Location of La Laguna Beneficio focusses attention on the need for satisfactory waste disposal. Because of proximity to San Salvador and the expressed interest, consideration should be given by Sanidad and the USOM Office to developing cooperative coffee waste research with officials of La Laguna Beneficio.

Tuesday, November 8, 1960

Messrs. Brewer, Batlle, Alfaro and the writer visited two beneficios at Santiago de Maria. The objective of this trip was to inspect beneficios that were operating in an area where water was scarce. We were accompanied by Paul Mendizabal, Region 7 Engineer.

We first visited Oromontique Beneficio owned by Prudencio Llach. We were shown through the plant by Armando Zepeda, Plant Manager, and Nicolas Maximiliano Lopez, Administrator. This beneficio has a maximum capacity of 1500 quintals of finished coffee in 24 hours. During the 1959 season, this beneficio processed 41,216 quintals of finished coffee, of which 23% was their own.

The only source of process water is rain water from roofs and patios, which is stored throughout the year. We were told that the Oromontique Beneficio used sixty gallons of fresh water per quintal of finished coffee. Pulp water amounts to five gallons per quintal of finished coffee indicat-

ing significant reuse. Water used to convey beans to the patios is returned to wash beans.

A considerable amount of new equipment had recently been installed. There were fifteen pulpers and it was reported that all pulpers were operated each time a batch of cherries was processed. Fermented beans were washed by passing through two centrifugal pumps operating in series. Washed beans are spread on patios where they are allowed to dry for one day. Final drying of the coffee beans is accomplished over a seventeen hour period in modern driers.

Pulp is conveyed from the pulpers through a two section rotary screen. Openings in the first section of the screen are relatively small to recover small beans and the second section of the screen contains large openings for recovery of larger coffee beans. Coffee pulp was dewatered on a vibrating screen and then dried on patios. The dry pulp was stored on the ground surface and covered with parchment. Coffee pulp is eventually used as fertilizer prior to the next coffee processing season.

Pulp water and fermentor water are discharged to a dry run in which dams have been constructed. The water seeps into the bed of the stream and the solids are recovered for use as fertilizer. The stream bed thus becomes a system of treatment and there is no water pollution.

In the afternoon, we visited the Coscafe Beneficio. This beneficio has been inoperative for three seasons. Coscafe officials had just recently taken possession of this beneficio as a means of satisfying heavy loans to the former management. We were shown through the beneficio by Jesus Rodriguez Berdugo, Administrator.

Like the Oromontique Beneficio, the only source of process water for Coscafe Beneficio is stored rain water. Santiago de Maria was reported to have one well, but most of the water apparently comes from a lake in the crater of the volcano overlooking the city. There were no data on water use available to the new management.

This beneficio was not operating but a number of workmen were engaged in getting equipment ready for starting up. There were eight pulpers of conventional design. Fermentation products will be washed from the coffee beans by passing through two open impeller pumps operating in series. Pulp will be pumped over mechanically cleaned plate screens. Screened pulp drops to a hopper conveniently located for truck loading.

Water draining from the pulp screen is collected in a pit along with fermentor drainage. Water overflows this pit into a second pit from which pumps return the water to the cherry pits and to the pulpers. This was the first completely closed water system that we observed. Provision was made for bringing in fresh water on the coffee bean washer and to add makeup to the pulp water system. The most interesting part of this beneficio was the closed pulp water system, which included drainage from the fermentors.

Wednesday, November 9, 1960

Mr. Brewer and the writer met for a short time with Mr. Valdivieso. The work that had been in progress during the writer's visit was briefly reviewed. Mr. Valdivieso expressed the opinion that the new Minister of Health would not change the policy toward the proposal of handling coffee pulp and liquid wastes in the Santa Ana area.

Mr. Valdivieso stated that Ricardo Perez desired Sanidad assistance in making hydraulic measurements at the Santa Ana beneficios. He expressed the opinion that Fertilizantes Salvadorenos S.A. may proceed with the fermentation process for handling coffee pulp. It is desirable to give this group as much assistance and guidance as possible on this project. This is especially true of liquid waste treatment.

Mr. Valdivieso reported that an alcohol plant was being planned to ferment sugar cane molasses. This central plant will be located approximately twelve kilometers (7.2 miles) from San Salvador. Interest was expressed in the bulletin prepared by Dr. Valsecchi on land disposal of alcohol wastes in the State of Sao Paulo, Brazil.

Attention was invited to the need for laboratory equipment and supplies. The writer offered to provide the names of suppliers of such equipment in the United States and current prices. This would include all of the equipment and reagents to run 5-day BOD's on ten samples daily, using three dilutions. Additional laboratory equipment would include:

1. BOD incubator
2. Steam bath for evaporation
3. Drying oven
4. Muffle furnace
5. Liquid level recorders

A survey of the coffee industry recently completed by Sanidad indicated that in the 1959 season there were 162 beneficios operating in El Salvador. A limited number of these beneficios have facilities for keeping coffee process wastes out of streams. The fact that there are at least 162 sources of coffee processing wastes is significant. The opinion was expressed that there might be as many as twelve additional beneficios operating in El Salvador during the 1960 coffee processing season.

The economics of the coffee industry in El Salvador can be best appreciated by considering the following values. Coffee cherries grown on low land are worth 70 colons for 500 pounds at the finca. Coffee grown on high ground brings premium prices of 75 colons per 500 pounds of raw cherries. This means that the finca owner realizes approximately 30 American dollars for each 500 pounds of raw cherries. This is equivalent to 30 cents per pound for finished coffee. Germany buys significant quantities of El Salvador coffee, for which they pay 100 colons per quintal or 40 cents per pound.

Contacts made during this El Salvador assignment are listed in Appendix F.

REVIEW OF TECHNICAL LITERATURE DEALING WITH CONTROL AND TREATMENT OF LIQUID WASTES RESULTING FROM THE PROCESSING OF COFFEE

There is a dearth of information in the technical literature dealing with control and treatment of coffee wastes. The most significant contributions known to the writer are in the form of a report and one published paper. These papers are too voluminous for inclusion in their entirety in this report. However, we are reproducing herewith the Introduction and the Summary and Conclusions for each report:

STUDIES OF THE TREATMENT OF COFFEE MILL WASTES (3)
BY ROBERT K. HORTON, MARIO PACHECO, MANUEL F. SANTANA
(OCTOBER 1946)

The fundamental objective of the research work presented herein was to find economical means for prevention of stream pollution and elimination of nuisances caused by liquid coffee wastes. At the outset it was hoped that economical methods could be found for treating wastes to such a degree that they could be reused in the coffee washing processes. Water resources in El Salvador are limited, particularly during the coffee season. If it were possible to reuse waste waters after treatment, then the value of the water returned for reuse would defray, at least in part, the cost of treatment. As a further result, the interest of the coffee industry in the problems of stream pollution and water conservation would be greatly intensified.

DESCRIPTION OF COFFEE PROCESSING

The processes included in coffee washing are as follows (1) Fresh coffee delivered at the mills is dumped into a receiving vat. From this vat the coffee is conveyed by water to pulping machines. By means of these machines the hull and some of the flesh, or pulp, is removed from the bean. After this process the coffee is transported by water to a fermentation vat. Here it is allowed to ferment in a moist state for periods varying from 12 to 48 hours. Before fermentation the flesh is insoluble and can not be washed or scrubbed off the parchment which immediately surrounds the bean. During the fermentation process the flesh is converted into products which are soluble or which are readily removed by washing. After the fermented coffee has been washed, it is conveyed, again by water, to drying patios. Drying requires several days, after which time the parchment is removed by dry milling.

From this it can be seen that two types of liquid wastes are produced by coffee processing. The first type, which is designated herein as pulping waste, consists of water used to transport coffee to and from the pulping machines, and also includes water used to convey the hull and initially remove pulp to a place of disposal.

The second type, called fermentation wash water waste, is the water which is used for washing fermented coffee and which is discharged after the coffee has been conveyed to the drying patios.

Coffee mills employ essentially a batch, or fill-and-draw method of operation. The number of hours a mill operates any day varies, depending upon the amount of fresh coffee received. In pulping operations, batches, or vats, of fresh coffee are taken and milled, more or less in turn. Also in the washing of fermented coffee, vats are washed in turn rather than all at the same time. It appears then that it would be more logical for a treatment plant designed for coffee wastes to employ also a batch method of operation. For this reason such a method of operation was employed throughout these studies.

DISCUSSION

The results of this research work have indicated in a general way the degree of purification in coffee mill wastes which may be expected by biological filtration and other methods of treatment. The results have also indicated some of the major difficulties encountered in the treatment of these wastes. The main difficulty in the treatment of pulping waste is that the B.O.D. of this waste is very great, and therefore the percentage of B.O.D. reduction required for a satisfactory effluent is extremely high. In treating fermentation wash water waste, the most serious problem is that of removing the colloidal gels which are present in large quantities.

The most promising results with fermentation wash water waste were obtained by chemical treatment after fermentation had been allowed to continue for several days. Attempts at precipitation of the fresh waste were completely unsuccessful. Additional research on treatment by continued fermentation is greatly needed. It is possible that treatment by such a method will prove to be effective also for pulping waste and for pulping and fermentation waste combined.

Results of the experiments made on recirculating filtration showed reductions in B.O.D. of from 64% to 92% after 6 hours of treatment. High rate, recirculating filters have been found to possess certain advantages over standard trickling filters, and also over other methods of biological treatment. Among the advantages of high rate filters may be mentioned the fact that smaller beds are used and therefore initial construction costs are reduced. A second advantage is that recirculation at high rates improves filter unloading by increasing the scour (3). One advantage that filters have over other methods of treatment is that they are better able to withstand sudden changes in strength and character of the incoming waste. This ability to withstand the shock of wide variations in initial strength is of great importance in the treatment of industrial wastes. In addition to these advantages, filter operation usually requires less expert supervision than some of the other methods of treatment. Finally, treatment by recirculating filtration lends itself very readily to a fill-and-draw method of operation. For these reasons, it appears that recirculating filtration will prove to be the most satisfactory and economical method for biological treatment of coffee wastes.

The degree of treatment required for wastes at any particular coffee mill will depend upon a number of factors. At some mills the objective may be to obtain an effluent which can be reused in coffee washing operations. If the objective is solely the abatement of stream pollution, then the degree of treatment necessary will be dependent upon the size and properties of the receiving stream. Once qualities of the effluent desired have been established, the type and degree of treatment will be governed by the strength and character of the raw wastes. It has been pointed out that raw wastes from different mills vary widely in characteristics. Therefore, the conclusion is that there is no universal answer to the coffee waste problem; each mill presents different conditions, and hence requires separate study before the most suitable method of treatment can be determined.

At some coffee mills disposal of wastes may be facilitated by collecting strongly concentrated discharges and weaker wash waters separately. In many cases it is possible that the weaker wash waters could be discharged directly into the nearest watercourse. Separate collection would therefore mean that treatment facilities would be required only for wastes which were highly concentrated but reduced in volume.

A number of existing coffee mills have effected large reductions in waste volume, with resulting increase in waste strength, by using principles of recirculation and counterflow of the processing water. In all cases, these principles of recirculation and counterflow have been adopted as devices for conserving the available water supply. The fundamental influence that they have on the volume and character of wastes discharged from a mill is readily seen.

The use of liquid wastes from coffee mills for irrigation has been suggested (1). It has been reported (1) that wastes which are not unusually high in solids content are not toxic to plant life. Where applicable, irrigation is of course an ideal method of waste disposal; and studies should be undertaken to determine fully the effects of coffee wastes upon land use.

Finally, the possibility of treating coffee wastes together with domestic sewage should not be overlooked. Investigations are needed to determine if successful treatment of combined wastes can be effected. It was impossible to make such investigations during this research program, because there was no collection system for domestic sewage in the small village where the pilot plant was located. At the present time very few towns where coffee mills are operating have sewer systems. However, as progress is made in the collection and treatment of both domestic and industrial wastes, the time may not be too distant when the purification of coffee wastes at plants treating domestic sewage will be the most desirable solution to the problem.

SUMMARY AND CONCLUSIONS

Wide variations are encountered in the strength and character of coffee wastes. Different mills discharge wastes which have different polluting qualities, and at any particular mill there are daily and hourly variations of considerable magnitude.

Of the two types of liquid discharges from coffee mills, pulping waste is the stronger and may at times have a B.O.D. as high as 15,000 p.p.m. Treatment and disposal of fermentation wash water waste, which has a lower B.O.D., is a serious problem mainly because of its bulky content of colloidal matter.

Coffee washing is done principally on a fill-and-draw method of operation; consequently, it appears logical for waste treatment plants to employ this method of operation also.

Plain sedimentation of coffee wastes does not ordinarily produce large reductions in B.O.D. In these studies a maximum reduction of 29% was obtained, but on most occasions the reduction was from zero to 10%.

High rate, recirculating filtration gave reductions in B.O.D. of fermentation wash water waste of 75.7% to 92.0% after six hours of treatment. With pulping waste, B.O.D. removals were 64.4% to 87.8%, and with combined waste removals were 82.9% to 88.6% after six hours of recirculation.

Chemical precipitation of fresh fermentation wash water waste was an unsuccessful method of treatment.

Results show that fermentation wash water waste can be treated satisfactorily after the waste has been held for several days, during which time the fermentation processes, or reactions, have been allowed to continue. Treatment by continued fermentation is highly deserving of further research.

If coffee wastes are to be reused, it will be necessary, in all liklihood, to follow ordinary chemical and biological methods of treatment by some finishing process, such as sand filtration or chlorination.

It is possible that disposal of coffee wastes can be facilitated by separate collection of concentrated discharges and the weaker wash waters.

Some mills, by employing principles of recirculation and counterflow of the processing water, have reduced the volume of wastes discharged, with a consequent increase in waste strength.

Disposal of coffee wastes by irrigation needs study.

Finally, there is no universal solution to the coffee waste problem; conditions at each mill must be studied before the most satisfactory method of waste disposal can be determined.

TREATMENT AND DISPOSAL OF WASTE WATERS FROM PROCESSING OF COFFEE (4)

By T. W. Brandon, Water Pollution Research Laboratory, Watford, England

For several years concern has been felt in East Africa about the pollution of streams by effluent discharged from coffee factories. The position has been aggravated by sub-normal rainfall and it has not infrequently happened that the

product of one coffee factory has been tainted by the presence in its water supply of effluents discharged by other factories higher up the same stream.

Between 1935 and 1939, a Committee appointed by the Water Board of Kenya investigated means of disposal of coffee effluents and published an interim report (1). Among the recommendations were that tank washings, together with effluent draining from fermentation tanks during pulping (tank effluent) should be discharged to seepage pits, and that the pulp heap should be so sited that the very polluting liquid draining from the pulp could not flow into streams. There is no doubt that a great improvement in the condition of the rivers could be achieved by adoption of the recommendations, but it was realized that much polluting matter would still be discharged from the factories. Arrangements were therefore made in 1946 for the Water Pollution Research Laboratory of the Department of Scientific and Industrial Research of Great Britain to undertake an investigation of the problems involved.

SUMMARY

Mixed waste waters produced during processing of coffee are equivalent in polluting character to about 60,000 gallons of crude domestic sewage for each ton of clean coffee produced.

About 85 per cent of the total polluting matter is produced during pulping, and 15 per cent during washing of the fermented beans.

The most polluting liquids were, in order; tank effluent, first tank washings, and pulp water.

By rapid separation of pulp from conveying water, 40 per cent of the pollution contributed by pulp water can be avoided. This is equivalent to nearly 20 per cent of the total polluting matter from all sources.

Laboratory experiments indicate that the polluting character of the mixed waste waters, or of pulp water alone, can be greatly reduced by natural fermentation, but difficulties might arise in operating this method at a factory.

The biochemical oxygen demand of the mixed waste waters was reduced by up to 50 per cent by treatment with chemical coagulants, but it was concluded that addition of coagulants would not be a suitable means of treatment, owing to the close control required and difficulties involved in disposal of sludge.

Experiments suggest that the most satisfactory method of treatment would be by biological filtration. The installation required to reduce the total polluting character by 94 per cent, at a factory producing one ton of clean coffee per day, would cost about 1,850 pounds.

In deciding which means of treatment is to be adopted, consideration should be given to local conditions, such as the degree of dilution available in the river to which the effluent is discharged and the requirements of other riparian owners. In deciding what size of plant is required, reference should be made

SECTION VI

MEMBRANE FILTER DELAYED INCUBATION PROCEDURE

The sample for the coliform examination is to be collected each week in a separate, sterile bottle, at the time that the collections are made for the chemical analyses. Examinations will be made by the membrane filter delayed incubation technique. Because of the nature of coliform organisms, it is very important that every effort be made to filter the sample, transfer the membranes to the preservative medium and mail to the SEC without undue delay. Samples of water shipped long distances into a central laboratory do not represent a true picture of the coliform populations present at the time of sample collection, if an undue delay has occurred. Do not collect samples on Thursday, as samples remain in shipment too long for satisfactory analysis.

SUPPLIES

The Public Health Service will provide the necessary filtration equipment to those cooperating laboratories which do not already have it on hand. All other necessary supplies will also be provided by the Service. The filtration apparatus and shipping containers for the samples are shown in Figure 7.

The PHS will provide, at intervals, the supplies listed below for the membrane filter coliform test. When the current supply of most or all of the items is exhausted, please return the shipping container with any unused materials to the SEC.

Each shipping container forwarded to the cooperating laboratory will contain:

M-Endo Broth MF (dehydrated)	1/4 pound
Denatured alcohol (25 ml.)	2 tubes
Sodium benzoate solution [12% aq. (25 ml.)]	2 tubes
Sterile ointment tins (3 tins/pack,	26 packs
Sterile MF filters with absorbent pads (10/pack)	8 packs
Phosphate buffer concentrate (20 ml.)	2 tubes
Mailing cartons	26 each
Addressed franked labels for cartons	26 each
Transmittal forms	26 each

to the production of clean coffee at each factory over a period of several years.

Provided the effluent is of reasonably good quality, it seems unlikely that use of filter effluent for factory operations would have any harmful effects on the quality of the coffee.

COMMENTS ON PUBLISHED MATERIAL ON COFFEE PROCESS WASTES

The quality of coffee wastes has been reasonably well established but the variations in concentration and volume reported leave some questions unanswered. The most striking differences are in the results of studies reported by Ward in El Salvador and by Brandon in East Africa(1) (4).

Studies were conducted by Ward during February and March 1944. Brandon has reported on coffee wastes research in East Africa during the period July-December 1946. These variations are revealed in the following unit values:

VOLUME, 5-DAY BOD, AND POPULATION EQUIVALENT PER QUINTAL OF FINISHED COFFEE

Criterion	El Salvador	East Africa
Volume (U.S. Gallons)	260	1080
5-Day BOD (Pounds)	3.2	10.9
Population Equivalent (BOD Basis)	19.2	65.4

These data indicate that coffee mills in East Africa use four times as much water as those in El Salvador. They further indicate that coffee wastes in Africa are much more concentrated than similar wastes in El Salvador; a factor of 3.4 is indicated for pounds of 5-day BOD produced.

Before challenging either set of data, it should be recalled that the pollution load from a given wet process usually increases with increase in water use. It could be the practice in East Africa to process riper coffee cherries than in El Salvador which would be expected to increase the concentration of liquid wastes. The African data do not include solids results which would have provided an excellent check on BOD values. It is entirely possible that the pulpers used in Africa may macerate the pulp to a greater extent than those employed in El Salvador. Even though several possibilities have been suggested, it would seem prudent to check these waste data in future research.

The high sugar content of coffee cherries has direct bearing on characteristics of the pulp and the liquid process wastes. Sugars in the pulp and in the foam which floats on the pulp water attract flies. In the past, flies have constituted a serious problem in the areas where coffee pulp is exposed. The Belgian publication Technologie Du Cafe (18) reports total sugars as high as 14.4% in coffee pulp and 9.3% in the coffee bean. These values are recorded in Chapter 2 entitled "Composition Chimique Du Fruit Et De La Feve".

Research conducted by both Horton and Brandon included pilot plant studies with biological filters. Efficiencies in BOD removal reported were encouraging. However, biological waste treatment systems are expensive to construct and operation charges are relatively high. It is difficult to justify the cost of such waste treatment systems for seasonal operation such as the coffee processing industry.

It is believed significant that both Brandon and Horton considered natural fermentation of coffee wastes. It would be interesting to check the rate of degradation in the existing lagoons at the Ateos Beneficio if this has not already been done by Sanidad. Brandon found that the pollutional characteristics of the mixed waste waters were reduced approximately 70% by storage in dishes for six days and by some 85% when stored for twelve days. Results reported by Brandon for natural fermentation of mixed coffee waste waters and coffee pulp water are tabulated on page 38.

The experimental work of Fertilizantes Salvadorenos in fermentation of coffee pulp at Santa Ana has been discussed at some length in Appendix B. In this discussion, the advantages of continuous mixing of the digester contents were cited. The benefits of continuous mixing were demonstrated by Professor Schroepfer and associates in research conducted at the George A. Hormel & Company Meat Packing Plant, Austin, Minnesota. This research showed that 66 turnovers in the digester per day gave 94% BOD removal whereas 20 turnovers per day lowered the BOD removal to 84.4%. This research is described in detail in Reference (19). The treatment system developed by Professor Schroepfer is referred to as "the anaerobic contact process".

The first full-scale plant employing the anaerobic contact process was installed at Wilson & Company, Inc., meat packing plant, at Albert Lea, Minnesota(20). This treatment works has been in operation for some five years and is giving excellent results. Mr. A. J. Steffen is scheduled to give a technical paper on the Albert Lea Plant at the Sixteenth Annual Purdue Industrial Waste Conference May 3, 1961. This Purdue paper should give useful information on operation as well as data. Reference 8 should also be reviewed.

It is possible that treatment of residual wastes from the processing of coffee could use anaerobic treatment in lagoons, followed by aerobic treatment in biological filters. This system was employed at one time by National Grain Yeast Corporation at Crystal Lake, Illinois. A combination system of this type would have the advantage of reducing the size of storage lagoons. If necessary, the filter effluent could be returned to the lagoon.

Available information indicates that coffee wastes may be deficient in phosphate. It would be desirable to investigate availability of nutrients in order to assure optimum growth in biological treatment systems. This subject is discussed in Reference (5).

AVERAGE RESULTS OF TREATMENT OF COFFEE WASTE WATERS BY NATURAL FERMENTATION

Period of fermentation (days)	Oxygen absorbed from acid permanganate in four hours at 26.7°C. (O.A.)	Biochemical oxygen demand in three days at 26.7°C. (B.O.D.)	Reduction in polluting character (per cent)	
	parts per 100,000		Based on O.A.	Based on B.O.D.
A. - Mixed Waste Waters				
0	174	176	-	-
1	107	152	39	14
2	91	114	48	35
4	64	80	63	55
6	36	55	79	69
8	32	33	82	81
12	28	27	84	85
B. - Pulp Water				
0	236	187	-	-
1	213	165	10	12
2	199	157	16	16
3	160	133	32	29
5	131	97	45	48
8	96	70	59	63
12	83	43	65	77

Reference is made to publications received from the University of Hawaii, Agricultural Extension Service (6) (7). Extension Circular 359 emphasizes the need to harvest only mature coffee berries. This publication urges prompt pulping of coffee, preferably on the same day it is harvested. These considerations undoubtedly could be related to liquid wastes as well as quality of the finished coffee.

Observations were made February 1, 1961 at a coffee mill owned and operated by American Factors Limited at Kailua-Kona, Hawaii. This plant employed mechanical demucilaging. Pulpers at the Kona mill are followed directly by a washer that provides agitation by a number of transverse pins on a vertical shaft which revolves within the washer. This type washer was reported effective in removal of the mucilage.

Five of the Hawaiian mechanical demucilaging machines were manufactured in Puerto Rico by Morovis. The address of the Puerto Rican company is:

Morovis
Fabricada Por
Maquinaria Cafetalera, Inc.
Bayamon, Puerto Rico
RFD 381

The Hawaiian coffee mill employed a sixth combination pulper and mechanical demucilaging machine. This unit was manufactured in Japan. Advantages claimed for mechanical demucilaging included:

1. Elimination of fermentation vats and a step in the process which occasionally damages the coffee bean

2. Elimination of shrinkage, which varies between 3% and 4% of the weight of green coffee during the fermentation process

The Hawaii Agricultural Experiment Station has investigated caustic treatment of freshly pulped coffee to remove the mucilage. Publication dates indicate that this work was preceded by the research of Carbonell and Vilanova at Santa Tecla, El Salvador (14). Although caustic has been proven effective in prompt removal of the mucilage from the coffee bean, the process has not been accepted by the industry. Dr. Vilanova explained that the need for closer control and possible discoloration of the coffee bean accounted for reluctance on the part of the coffee industry to use alkali hydrolysis in lieu of natural fermentation.

Mr. Valdivieso and his associates have given much thought to composting coffee pulp with subsequent return to the fincas as fertilizer (15) (16). Dr. Fernando Suarez de Castro at Santa Tecla has likewise studied the use of coffee pulp as fertilizer both in Columbia, South America, and in El Salvador (17). Dr. Castro is enthusiastic about the use of coffee pulp as fertilizer and believes that composting coffee pulp shows most promise for the majority

of beneficios in El Salvador. Observations made by Mr. Valdivieso lead to the conclusion that it is virtually impossible to control flies at the fincas because the farmers cannot be depended upon to work the coffee pulp into the soil. The subject of composting organic material such as coffee pulp has been investigated in various parts of the world and much has been written on this subject (9) (10).

Seasonal operation of the coffee processing industry dictates a minimum of capital investment in waste treatment facilities. The vegetable and fruit canning industries are confronted with the same problems. During the past several years, there has been a definite trend in the canning industries in the United States to employ land disposal (11). Storage lagoons have been used by the canning industry in the United States for some fifty years. More recently spray irrigation, and ridge and furrow irrigation, have been employed with considerable success. Land disposal has been extended to dairy wastes, tannery wastes, and spent sulfite liquor with varying degrees of success. It is believed that the coffee industry in El Salvador may find land disposal of concentrated process wastes feasible in numerous areas.

It has been suggested that combined treatment of domestic sewage and coffee process wastes may eventually prove feasible in El Salvador. Again, there is a definite trend toward combined treatment in the United States and Europe. This stems from the fact that fixed costs and operation charges are less for one large treatment works than they are for two smaller plants. These advantages are offset by seasonal operations which result in either overload during the coffee processing season or over capacity in the treatment works during the remainder of the year.

Certain municipalities in the United States have had outstanding success with combined treatment of domestic and trade wastes. Foremost in this field is Mr. L. S. Kraus, General Manager of the Greater Peoria Sanitary District, Peoria, Illinois. The Peoria plant uses the diffused air activated sludge process. This plant handles domestic sewage from some 125,000 people with a like amount of organic wastes from industry. Mr. Kraus has been granted several patents on improvements to the activated sludge process. Mr. Kraus is also an authority on fermentation (anaerobic digestion) of industrial wastes, having worked closely with Commercial Solvents Corporation, Standard Brands Inc. and other large industrial corporations. Mr. Kraus serves as a consultant to a number of industries on their waste treatment problems (12).

It has been brought out that water use varies considerably with the different beneficios in El Salvador. This is even more striking when comparing water use in El Salvador with that in Africa. The subject of water use and reuse was discussed with a number of beneficio operators in El Salvador. It has been concluded from these conferences and observations that pulp water can be reused without impairing the quality of the finished coffee. However, when an abundance of water is available, the beneficio operators invariably prefer using fresh water. Inasmuch as the cost of waste treatment and/or disposal is usually influenced by volume, it is reasonable to expect that the solution to waste handling problems may well be integrated with fresh water use.

FUTURE RESEARCH ON COFFEE WASTES

Future research on solid and liquid wastes resulting from the processing of coffee in El Salvador can best be undertaken as a joint project. The principal agencies cooperating in this joint research should be the Instituto Salvadoreno de Investigaciones del Cafe, Sanidad, and USCN. Representatives of Fertilizantes Salvadorenos S.A. should actively participate in all research on fermentation of coffee pulp and concentrated coffee process wastes. Full cooperation of representative beneficios will be essential. Some of the proposed research can be conducted simultaneously. The research program should be designed to produce practical solutions to the following problems:

1. Process wastes should be correlated with the raw material and the processes employed. Although maturity of the cherry is a relative matter, it should be possible to determine the difference in wastes when processing ripe cherries and when operating on relatively greenfruit. Likewise, the effect of storage of the cherries before pulping should be assessed. Waste results should be reduced to unit values per quintal of finished coffee.

2. The pilot plant demonstration of Fertilizantes Salvadorenos S.A. on fermentation of coffee pulp focuses attention on this process. This proposed project contemplates pumping coffee pulp from nine beneficios to a central plant. Liquid residual wastes will require treatment. It would seem logical to extend this system of treatment to the liquid wastes.

3. Brandon demonstrated that the biochemical oxygen demand of pulp water was almost doubled during the first fifteen seconds of contact. The BOD of the pulp water increased with continued contact with the pulp after fifteen seconds, but at a much slower rate. Reuse of pulp water will further increase its organic content. The effect of pulp water reuse on the pollution load from a given beneficio should be determined before this practice is urged as a pollution abatement measure. It should be possible to establish tolerable limits for quality of pulp water reused.

4. The rate of natural purification in coffee waste lagoons should be determined. Results reported by Brandon and recorded on page 38 of this report indicate rapid fermentation. These studies could lead to drastic reduction in the lagoon storage required for a given beneficio.

5. Because of faculative organisms, it is possible to go directly from an anaerobic treatment system to an aerobic treatment system. This suggests biological filtration or brush aeration of coffee wastes after natural fermentation in a lagoon. This experimental work could lead to economical treatment. This system would permit returning filter effluent to the lagoon until biological growths within the filter reached a level that provided an acceptable effluent.

6. The success achieved with land disposal of liquid wastes from seasonal industries warrants exploring application of this disposal method to liquid wastes from processing coffee. This system of disposal would appear well suited to the drier areas in El Salvador. This study should include an evaluation by agronomists on the effects of these wastes on soil fertility.

The foregoing programs are suggested as reasonable and practicable projects which will provide engineering and analytical data essential to solutions for treatment and disposal of both solid and liquid wastes resulting from processing coffee. Some of these questions can be answered by a comprehensive industrial waste survey at one or more representative beneficios. Each project should be organized and staffed to produce the maximum results for the effort expended.

APPENDIX A

AIRGRAM

INTERNATIONAL COOPERATION ADMINISTRATION

August 26, 1960

From: U. S. Operations Mission to El Salvador

Subject: Short Term Consultation on Industrial Wastes

Wastes from coffee processing plants are polluting most of the surface waters of El Salvador to the extent that this valuable natural resource is no longer usable for many domestic, agricultural, and industrial needs. Abatement of the pollution presents problems that involves both industry and government and requires that cooperative action be taken to find practical solutions.

The Division of Water Supply and Pollution Control of the U.S. Public Health Service has had considerable experience in promoting cooperative industry government investigations and actions on industrial wastes, and has the staff and facilities to provide technical backstopping for such investigations.

USOM/El Salvador has been asked by the Ministry of Health to provide technical assistance on the problem of coffee wastes, and the association of coffee processers has indicated a willingness to cooperate. Provision of this assistance needs to be concurrent with the coffee harvest which begins in October.

It is believed that valuable assistance can be given by the Division of Water Supply and Pollution Control of the U.S.P.H.S. in the organization of an industry-government investigation of this problem. Their staff members at the Sanitary Engineering Center, Cincinnati, Ohio are familiar with this problem and are capable of providing an Industrial Waste Consultant for a short term assignment.

USOM/El Salvador requests the services on a reimbursable basis for a period of four weeks beginning about October 17, 1960 of the following person:

Hayse H. Black, Industrial Waste Consultant, Water Supply
and Pollution Control, U. S. Public Health Service,
Robert A. Taft Sanitary Engineering Center
4676 Columbia Parkway, Cincinnati 26, Ohio

It is necessary that this short term consultation begin at approximately the October date specified above. Delay beyond that date will find the coffee processing season too far advanced to organize the proposed investigation. Please advise on availability, date of arrival, and estimate of charges for the consultant.

MILLER

APPENDIX B

San Salvador, October 27, 1960

To: Coffee Wastes File

From: Hayse H. Black
Industrial Wastes Consultant
Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

Subject: Comments on Bihugas Project for "El Molino"

During our visit to "Beneficio El Molino", Santa Ana, October 20, 1960, we met and conferred with Mr. Alfonso Alvarez, Mr. Ricardo Perez, and Dr. Victor Ortiz. These men invited our inspection of the pilot plant which has been used to study fermentation of coffee pulp. In connection with this visit, our attention was directed to reports prepared by Ferdinand Schmidt and Dr.Ing. Walter Eggersgluss, Verden (Aller), Germany. Subsequent to this visit, we conferred with Dr. Victor Ortiz, Friday October 21, and Mr. R. Perez, October 24, 1960. Based on these conferences and review of the reports referred to, we offer the following comments:

1. The proposal to ferment coffee pulp to produce combustible gas is commendable. This process converts sugars and readily decomposable organic materials to methane and carbon dioxide leaving a residue suitable as fertilizer. Conversion of the sugars to gas not only produces useful by-products but also alleviates the fly problem.

2. This project contemplates processing an annual production of 32,660 long tons of coffee pulp. This represents the pulp from 20% of all coffee produced in El Salvador. This central plant will serve nine beneficios located in the Santa Ana area.

3. Operation of the pilot plant on coffee pulp from a silo has demonstrated thermophilic fermentation to produce reasonable quantities of satisfactory quality gas. Questions to be resolved include optimum organic loading, desirable retention, preferred system of mixing, drying of the sludge, and disposal of liquid wastes.

4. It is proposed to remove fresh coffee pulp from each beneficio by diluting it with liquid process wastes and then pumping to the central plant for processing. It is stated that the diluted pulp will be centrifuged at the central plant for removal of water. The reports referred to do not mention experimental work with centrifuges. We would expect pumping of the pulp and centrifuging to dissolve additional sugars and organic material which would appear in the centrifuge liquor. Surplus coffee pulp will be stored in four trench silos at the central plant.

5. It is estimated that gas will be produced at the rate of 6,820 cubic meters per 24 hours. It is proposed to build a gas holder having a cap-

APPENDIX B (Cont'd)

a acity of 4,000 cubic meters which represents 14.4 hours gas production. This limited storage dictates use of gas as produced. Additional gas storage would be desirable.

6. Two storage silos are proposed which will provide approximately 13 days storage for sludge withdrawn from the fermentors. When the coffee pulp storage tanks are filled, it will be necessary to remove fermented sludge from the premises promptly. Sludge storage could become a real problem.

7. Concentration of sludge withdrawn from the fermentors has been computed at 11% total solid. This concentration is considered too wet for transportation. It is proposed to dewater this sludge to 25.4% total solids by vacuum filtration. Sludge of this character is frequently very difficult to dewater. In fact, some sludges defy dewatering. Reports covering this project do not refer to vacuum filtration experiments.

8. Theoretical retention in the digestors has not been given. If our interpretation is correct, this could be as long as six weeks considering the system of feeding proposed. Fermentor operation can be controlled by testing for volatile acids and maintaining acidity below 2000 ppm. Operation problems can be predicted by pilot plant observations.

9. Recent research on anaerobic fermentation of meat packing wastes in the U. S. has proven the desirability of continuous mixing in the fermentors. Continuous mixing improves efficiency and reduces retention in the digesters. The system proposed for Santa Ana provides two pumps for circulation of liquor 15 to 30 minutes daily in each of the eight digesters. In the United States, Wilson and Company treat Meat Packing Wastes at their Albert Lea, Minnesota plant employing fermentation and continuous mixing to remove 95% of the biochemical oxygen demand with 12 hours retention.

10. The reports referred to have been prepared without first hand knowledge of construction problems. Engineers handling this design should have the benefit of field inspection.

11. Production of methane from sewage solids is common practice in waste treatment. A number of gas engines are in operation using this gas to generate electricity. Limited financial returns are being realized from these capital investments. Large scale fermentation of coffee pulp to produce methane for generation of power represents a pioneering effort. Cost estimates and computed return for this project should be considered tentative.

12. The reports referred to pertain only to fermentation of coffee pulp. There is no mention of treatment for residual liquid wastes. It is conceivable that residual liquid wastes resulting from pumping, centrifuging, and filtration of sludge, could aggravate rather than improve the stream pollution problem. Treatment of residual liquid wastes should be made an integral part of this project.

APPENDIX B (Cont'd)

13. The importance of this problem to the El Salvador coffee industry warrants a thorough engineering investigation to resolve pertinent questions and to provide engineering data on which to base design of appropriate treatment works.

REPORTS PERTAINING TO COFFEE PULP FERMENTATION AT SANTA ANA, EL SALVADOR

1. A. G. Ferrestaal, Essen, Germany, by Ferdinand Schmidt, August 23, 1960

2. Development of the Bihugas Plant Allerhop - Its Capacity and Economical Efficiency, by Ferdinand Schmidt, January 9, 1951

3. Experience of Operation and Reflections About the Economy of the Bihugas Plant, Allerhop, by Dr. Ing. W. Eggersgluss

4. Report About the Manuring Experiments with Putrid Sludge in Allerhop, by Prof. W. Sauerlandt, Agricultural Research Institute, Braunschweig, Veelkenrode

5. Preliminary Report About the Circulation of Substance in the Bihugas Plant, by Dr. H. Welte, Agricultural Chemical Institute University, Goettingen

6. Bihugas as a Moter Fuel for Combustion Engines, Short Report by Dr. Ing. Kloss - Kloekner - Humboldt-Deutz A. G. Colegne-Deutz

7. Production of High Powered Gas from Agricultural Wastes or Other Organic Matter, by Ferdinand Schmidt and Dr. Walter Eggersgluss - World Power Conference, Rio de Janeiro, 1954

APPENDIX C

San Salvador, October 27, 1960

TREATMENT OF COFFEE WASTES

Liquid wastes from processing coffee are organic in nature and have been proven amenable to biological treatment. Investigation of volume and character of liquid wastes was made in El Salvador during the 1943-1944 Coffee Season. During the 1945-1946 season studies were made with high rate biological filters. Biological filters were likewise studied at a KIAMBU factory in East Africa during the main picking season in 1946. Results of these three studies appear in the technical literature. Pilot plant studies of anaerobic fermentation of coffee pulp taken from silos have been conducted during the summer of 1960 in Santa Ana.

Review of published and unpublished data for coffee waste studies reveals major variation in water use and waste concentration. It is known that quantities and degree of ripeness of the cherries being processed will explain some of these variations. The influence of these factors on the wastes produced can only be determined by additional observations.

Treatment of coffee process wastes for recovery of valuable pulp solids would seem to be a justifiable minimum requirement. This would include screening or brief sedimentation or both. Pulp solids can be used as fertilizer, cattle feed, or fermented to produce gas which in turn can be converted to power. Weaker liquid wastes can be subjected to aerobic biological treatment to reduce their pollutional effect on receiving waters.

Each beneficio possesses inherent variables in the way of equipment, operation procedures, water supply, and available dilution in the receiving stream. At Santa Ana, proximity of nine beneficios invites processing of pulp and treatment of residual liquid wastes at one central plant. Technical aspects and economics of this plan are being explored. When beneficios are remotely located, liquid waste treatment should be considered an individual and separate problem.

There are certain operations that, if adopted, should reduce the quantity of liquid wastes from processing of coffee. Reuse of water where feasible would be expected to reduce total discharge and net pollutional constituents. Prompt removal of pulp from process water by efficient screening will likewise reduce waste and increase byproduct recovery. Good housekeeping practice has paid dividends in similar industrial processes and should prove equally profitable to the coffee industry.

It is believed that control and treatment of liquid wastes from processing coffee should be approached at each beneficio by a multi-phase program in the following order:

1. Remove pulp silo drainage and, if possible, fermentor water from plant effluent and dispose of these liquors in seepage pits.

APPENDIX C (Cont'd)

2. Reduce water use where possible and instigate water reuse where feasible.

3. Promptly remove pulp suspended solids from process water by efficient screening.

4. Provide sedimentation basins for removal of settleable solids from combined plant effluent and include recovered solids with pulp for disposal.

5. In those areas where a higher degree of treatment is needed for protection of the receiving stream, one of the following systems should follow plain sedimentation:

    a. Lagoon for storage of liquid wastes with controlled release to the receiving stream at flood stage.

    b. Stabilization ponds designed to provide adequate treatment.

    c. Biological treatment which could be either aerobic or anaerobic depending upon organic solids concentration.

APPENDIX D

San Salvador, October 27, 1960

To: Record

From: Hayse H. Black
Industrial Wastes Consultant
Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

Subject: Coffee Process Wastes Investigation
1960 - 1961 Season

Based on present knowledge of problems related to processing of coffee pulp and the treatment of liquid wastes, it is suggested that the following program be adopted by SCISP for the 1960-1961 coffee season:

1. Provide consulting service to Ricardo Perez, President, Fertilizantes Salvadorenos, S. A. and his associates in their continued research on fermentation of coffee pulp at Santa Ana.

2. Insofar as resources permit, investigate residual liquid wastes from transportation and fermentation of coffee pulp as proposed for Santa Ana and explore treatment of same.

3. Study water use and water reuse at five or more representative beneficios with the objective of collecting engineering data.

4. Inspect systems for control and treatment of liquid wastes from processing coffee which are now being used in El Salvador, including such promising process changes as chemical treatment in lieu of fermentation for removal of protopectine from the parchment of the coffee bean.

5. Plan a program for collection of analytical data, at the earliest practical date, which will clarify published data and provide information on which to base treatment works design.

6. Develop, in cooperation with Sanidad, effluent criteria objectives for both municipal and trade wastes with special reference to coffee.

7. Organize a program, in cooperation with Sanidad, for upgrading the sanitary quality of surface waters of El Salvador in order to restore this valuable resource.

APPENDIX B

DATOS SOBRE PULPA DE CAFE

1.— qq. de cafe uva fresca se descompone asi:

Pulpa	40 %
Mucilago	20 %
Pergamino	40 %

1.— qq. de cafe seco se descompone asi:

Pulpa	26 %
Mucilago	14 %
Pergamino	60 %

Composicion del Mucilago de cafe:

Agua
Pectina
Azucares
Acidos organicos

Composicion Quimica de la pulpa fresca de cafe: (El Salvador)

Agua	60.00 %
Materia organica	38.12 %
Residuo Mineral	1.29 % (cenizas)
Nitrogeno	0.59 %

Composicion de la pulpa de cafe: (El Salvador)

Humedad	75 %
Nitrogeno total	1.40 %
Acido Fosforico (P_2O_5	0.321%
Potasa (K_2O)	3.71 %
Magnesio (M_gO)	0.166%

Composicion de la pulpa de cafe: (Colombia)

Humedad	74%
Ceniza	2.68%
Nitrogeno total	1.7 %
Fosforo total (P)	0.05%
Potasa (K_2O)	1.06%

APPENDIX B (Cont'd - 2)

Composicion de la pulpa de cafe: (Costa Rica)

Humedad	76 %
Nitrogeno	1.56 %
Fosforo (P)	0.16 %
Potasio (K)	2.43 %
Calcio (Ca)	0.45 %
Magnesio (Mg)	0.07 %
Azufre (S)	0.11 %
Hierro (Fe)	90 partes por millon
Manganeso (Mn)	8 " " "
Boro (B)	17 " " "

Composicion de las cenizas de la pulpa:

Acidio fosforico	10.33 %
Potasio	52.99 %
Calcio	3.80 %
Magnesio	7.60 %
Acido sulfurico	3.27 %
Cloro	0.82 %
Otros	21.19 %

Composicion de Nutrientes de la pulpa seca:

Materia seca Total ..... 81.3 %

Composicion promedio:

Proteinas	9.0 %
Grasas	1.7 %
Fibra cruda	19.3 %
Extracto libre de Nitrogeno	60.2 %
Materia Mineral	9.8 %

Coeficientes de Digestibilidad:

Proteinas	34.0 %
Grasas	97.9 %
Fibra cruda	87.7 %
Extracto libre de Nitrogeno	76.4 %
Proteinas digestibles ..	3.1 %
Nutrientes digestibles total	69.7 %

APPENDIX B (Cont'd - 3)

Otros analisis de Pulpa Seca:

N —	1.4 %
P —	0.14 %
K —	3.08 %
Mg.	0.10 %

-o-

Cenizas	68.00 %
Proteinas	11.23 %
Grasas	1.73 %
Cafeina	0.88 %
Fibra cruda	13.16 %
Carbohidratos	66.13 %

-o-

Materia seca	94.50 %
Proteinas	13.— %
Fibra cruda	19.70 %
Extracto libre de Nitrogeno	50.10 %
Cenizas	9.— %

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100 libras de cafe en uva despulpada a mano dieron 43 libras de pulpa.-

-o-

Received from

RICARDO PEREZ

APPENDIX F

CONTACTS MADE DURING EL SALVADOR ASSIGNMENT

Robert Brewer	U.S.O.M.	San Salvador
Col. Harry W. Miller	U.S.O.M.	San Salvador
Dr. Lamar A. Byers	U.S.O.M.	San Salvador
Clinton Smith	U.S.O.M.	San Salvador
Asa Walker	U.S.O.M.	San Salvador
Shelby Cain	U.S.O.M.	Santa Tecla
Juan Balette	U.S.O.M.	Santa Tecla
J. Alfonso Valdivieso	Sanidad	San Salvador
Dr. Roberto Arevalo	Sanidad	San Salvador
Jorge Alfaro	Sanidad	San Salvador
Alfredo Batlle	Sanidad	San Salvador
Guillermo Arbizu	Sanidad	San Salvador
Domingo Sossa	Sanidad Region 3	Santa Tecla
Raul Mendizabal	Sanidad Region 7	Santiago de Maria
Tomas Vilanova	Institute del Cafe	Santa Tecla
Fernando Suarez de Castro	Institute del Cafe	Santa Tecla
Flora Espinoza	Institute del Cafe	Santa Tecla
Ricardo Perez	Fertilizantes Salvadorenos	Santa Ana
Eduardo Alvarez	Fertilizantes Salvadorenos	Santa Ana
Adolfo McEntee	Fertilizantes Salvadorenos	Santa Ana
Dr. Victor Ortiz	Consultant	San Salvador
Frank Wager	Rio Zarco Beneficio	Santa Ana
Alfonso Alvarez	El Molino Beneficio	Santa Ana
Alfredo Schonborn	Ateos Beneficio	Ateos
Roberto Pacas	Pasatiempo Beneficio	Santa Ana
Guillermo Montoya	Pacatiempo Beneficio	Pan American Hwy.
Walter T. Deininger	La Laguna Beneficio	San Salvador
Francisco Altschul	La Laguna Beneficio	San Salvador
Armando Zepeda	Oromontique Beneficio	Santiago de Maria
Nicolas Maximiliano Lopez	Oromontique Beneficio	Santiago de Maria
Jesus Rodriguez Berdugo	Coscafe Beneficio	Santiago de Maria

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